CONSTRUCTION — EXPERIMENTAL — THEORY

NEWNES COMPLETE WIRELESS

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

1/-

IN WEEKLY PARTS

Quick Links

Introduction

COMPLETE WIRELESS

A PRACTICAL AND AUTHORITATIVE WORK FOR EVERYONE INTERESTED IN THE WIRELESS INDUSTRY

General Editor :

EDWARD MOLLOY

Advisory Editor :

RALPH STRANGER

VOL. I

Contributors to Vol. I :

S. R. MULLARD, M.I.E.E.
L. McMICHAEL, A.M.I.E.E.
L. D. MACGREGOR
H. E. J. BUTLER
R. C. WALKER, B.Sc.
J. H. A. WHITEHOUSE
L. H. FITZ-GIBBON
C. H. HAYWARD
E. W. HOBBS, A.I.N.A.
NOEL ASHBRIDGE, B.Sc., Chief Engineer, B.B.C.
RALPH STRANGER
W. F. FLOYD, B.Sc. (Lond.)
H. W. JOHNSON
HARLEY CARTER
JAMES H. BOOT
H. H. DOWSETT
A. PINK
FRANK PRESTON, F.R.A.

GEORGE NEWNES LIMITED
SOUTHAMPTON STREET, LONDON, W.C.2

Index and Classified Key enabling all articles on any particular subject to be readily turned up will be found at the end of the Complete Work.

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD., LONDON AND TONBRIDGE.

PREFACE TO VOL. I

THIS volume contains much to interest everyone in the Radio Industry as well as enthusiastic amateurs. Two items of outstanding interest are the series of articles which deal respectively with " Wireless Theory Made Plain " and " Servicing of Standard Sets."

The first mentioned series has been written by the Advisory Editor, Mr. Ralph Stranger. Mr. Stranger is already well known for his articles which have appeared in serial form in *World Radio*, and also for his books which have been issued under the title of " Ralph Stranger's Wireless Library." A feature which renders these articles of special value is the fact that the author has throughout based all his explanations upon the most modern theories which regard the electric current as a flow of electrons from the negative to the positive. Even those readers who are familiar with the older text-books dealing with electrical theory will find much to interest them in Ralph Stranger's lucid exposition of the subject. The photographs used to illustrate theoretical principles are also worthy of special attention.

The second series deals with the Servicing of the following standard makes of wireless receivers :—

Ekco
Pye
His Master's Voice
Edison Bell.

It is obvious that no one man could be expert on every type of receiver. Therefore, for the compilation of these articles we arranged to have each written by a technical expert attached to the firm responsible for the design and manufacture of the particular set dealt with. This, coupled with the fact that skilled photographers have been employed to secure pictures illustrating practical methods of dismantling and adjusting, has enabled us to produce a series which forms a valuable addition to existing wireless literature.

We leave the reader to look through the pages of the present volume, where he will find scores of other items which will provide him with hours of informative and instructive reading.

E. M.

iv

CONTENTS

COMPLETE WIRELESS

A PRACTICAL AND AUTHORITATIVE WORK FOR EVERYONE INTERESTED IN THE WIRELESS INDUSTRY

General Editor :

EDWARD MOLLOY

Advisory Editor :

RALPH STRANGER

VOL. II

Contributors to Vol. II :

SIR AMBROSE FLEMING F.R.S.
F. H. HAYNES
W. R. G. BAKER, Vice-President of RCA Victor Co. Inc.
E. W. HOBBS, A.I.N.A.
HARLEY CARTER
J. A. WHITEHOUSE
F. A. BOYCE
R. HARCOURT WOODALL, A.M.I.E.E.
J. ROBINSON, D.Sc. Ph.D. M.I.E.E.
RALPH STRANGER
W. F. FLOYD, B.Sc. (Lond.)
L. D. MACGREGOR
H. E. J. BUTLER
A. J. HARRIS
A. GOOTNICK
G. H. WATSON
FRANK PRESTON, F.R.A.

GEORGE NEWNES LIMITED
SOUTHAMPTON STREET, LONDON, W.C.2

ii

Index and Classified Key enabling all articles on any particular subject to be readily turned up will be found at the end of the Complete Work.

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD., LONDON AND TONBRIDGE.

PREFACE TO VOL. II

WE have been fortunate in securing as a contributor to this volume Sir J. Ambrose Fleming, F.R.S. Sir Ambrose Fleming was the discoverer of the two-electrode valve from which all other wireless valves have been developed. Had it not been for the research work conducted by Sir Ambrose many years ago it is highly probable that broadcasting would be unknown to-day, and the art of wireless transmission and reception would still be confined to purely commercial purposes. This is a very striking example of how a discovery made by a scientific worker may be the means of starting a flourishing industry and providing a means of livelihood for many thousands of people all over the world. Sir Ambrose Fleming's article, "The Nature and Properties of Wireless Waves," will command the interest and respect of every reader of this work.

Further additions to the series of Servicing articles include the following :—

McMichael.
Burgoyne.
Marconiphone.
Philips.
Columbia.

It has been suggested that these articles will soon become out-of-date, but this is not the case. There are thousands of each make now in use. These have cost their owners anything from £10 to £40 each. Whilst it is not suggested that radio reception has reached such a stage that no further improvements are possible, it can be said that every one of the sets dealt with in this series is capable of giving first-class reception. Therefore, they are not likely to be discarded for several years. When the fortunate owner of, say, a Philips Super Inductance Receiver decides to replace it by a later type, his existing model will, we think, most certainly not be relegated to the scrap heap ; it will be sold or presented to someone else. *These Servicing articles will, therefore, become increasingly valuable for some years,* as it may be assumed that wireless sets, like motor cars, will require more servicing the older they become.

Amongst the wonderful selection of other articles in this volume special mention may be made of "Radio Power Plant," "The Trend of Development in American Radio Reception," "The Superheterodyne," and "The Stenode." As an example of the authoritativeness of the work attention is drawn to the fact that the article on the Stenode has been contributed by Dr. J. Robinson, the inventor of this particular circuit.

E. M.

iv

CONTENTS

COMPLETE WIRELESS

A PRACTICAL AND AUTHORITATIVE WORK FOR EVERYONE INTERESTED IN THE WIRELESS INDUSTRY

General Editor :
EDWARD MOLLOY

Advisory Editor :
RALPH STRANGER

VOL. III

Contributors to Vol. III :

F. W. LANCHESTER, LL.D., F.R.S.
FRANK PRESTON
L. D. MACGREGOR
H. E. J. BUTLER
G. S. HOLIDAY
EDWARD W. HOBBS, A.I.N.A.
RALPH STRANGER
W. F. FLOYD, B.Sc. (Lond.)
J. H. A. WHITEHOUSE
H. J. BARTON CHAPPLE, A.M.I.E.E.
W. GEORGE
L. G. WARNER

GEORGE NEWNES LIMITED
SOUTHAMPTON STREET, LONDON, W.C.2

ii

Index and Classified Key enabling all articles on any particular subject to be readily turned up will be found at the end of the Complete Work.

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD., LONDON AND TONBRIDGE.

PREFACE TO VOL. III

THE first article in this volume is one that should be read carefully by every reader of this work. It deals with the theory of the thermionic valve, and is a very clear exposition of this important subject, which should be thoroughly digested by everyone in the radio industry who wishes to understand what happens inside the valve. This article is one of several in this volume which deal with the subject of valves, others of special interest being those dealing with the mathematics of the valve and the use of variable-mu valves.

Another feature of special interest is the section on "Valve Coupling Systems," which shows diagrammatically practically every conceivable method of coupling between valves, and which will be found invaluable for reference purposes. The subject of coupling systems is also dealt at some length in the article on "Receiver Design."

Special attention has also been paid in this volume to Electric Gramophone Motors and Gramophone Pick-ups, including a thorough treatment of the Automatic Record Changer.

Further additions to the series of Servicing articles include the following :—

Ultra
Philco
His Master's Voice
Marconiphone
Majestic
Baird Televisor

The latter is of interest in view of the B.B.C. broadcasts. The general subject of television, including all modern systems, will be dealt with later. Important developments in this subject are expected in the near future, and the subject is one with which everyone interested in the radio industry should be acquainted.

An article of special interest to wireless dealers is that on "Battery Charging Methods," while special mention may also be made of "Dual Balanced Loud Speakers and Amplifiers," and "Making a Start in Amateur Transmission." Although the latter will only be of direct use to a limited number of readers, it is a phase of wireless which should not be lost sight of. The work of the serious amateur has been of great importance in the rapid development and improvement of wireless receiving sets.

E. M.

CONTENTS

COMPLETE WIRELESS

A PRACTICAL AND AUTHORITATIVE WORK FOR EVERYONE INTERESTED IN THE WIRELESS INDUSTRY

General Editor :

EDWARD MOLLOY

Advisory Editor :

RALPH STRANGER

VOL. IV

Contributors to Vol. IV :

SIR OLIVER LODGE, F.R.S.
J. P. McKENZIE, A.M.I.E.E.
FRANK PRESTON, F.R.A.
EDWARD W. HOBBS, A.I.N.A.
A. E. WATKINS
G. S. HOLIDAY
ALAN POLLOCK
H. H. DOWSETT
D. ASHBY, A.C.G.I., B.Sc., D.I.C.
C. F. ELWELL, Fell. Inst. Rad. Eng., M.I.E.E.
RALPH STRANGER
H. E. J. BUTLER
W. F. FLOYD, B.Sc. (Lond.)
W. W. WHIFFIN
J. H. A. WHITEHOUSE
T. SUTTON BRIGG
ERIC J. RIGBY, A.M.I.E.T., M.T.R.A.

GEORGE NEWNES LIMITED
SOUTHAMPTON STREET, LONDON, W.C.2

Index and Classified Key enabling all articles on any particular subject to be readily turned up will be found at the end of the Complete Work.

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD., LONDON AND TONBRIDGE.

PREFACE TO VOL. IV

WE have been particularly fortunate in securing as a contributor to this volume Sir Oliver Lodge, F.R.S., whose article on "The Principle of Tuning" is of great interest. As will be seen, the patent which Sir Oliver took out in 1897 was the bottom patent for tuning to the end of its life, and it is interesting to note that it was considered to be of such importance that a seven years' extension of the patent was granted. It can safely be said that it is as a result of this patent that there is to-day a dial on every receiving set, whereby it can be put into tune with any transmitter, so that it readily responds to that one and to no other.

In view of the increasing interest taken in short-wave broadcasting, which has been greatly fostered by the British Broadcasting Corporation's Empire scheme, this subject has been dealt with thoroughly from the point of view of the man who wishes to construct a separate short-wave receiver, or convert his existing set for short-wave reception.

Amongst the recent developments in wireless which are dealt with in this volume, mention may be made of the articles dealing with "A Screened-grid Quiescent Push-pull Circuit," "Double Push-pull Receiver," "Push-push Amplification" and "The Quiescent Four"; while other developments dealt with include "Automatic Volume Control," "Tone Control," and "Automatic Grid Bias."

Another subject which we think will interest many readers is that dealing with "Sound Recording at Home." Whilst, of course, it must be borne in mind that wireless programmes are the property of the British Broadcasting Corporation and must not be reproduced, it will be readily apparent that there is wide scope for obtaining plenty of amusement with home recording apparatus.

We have continued in this volume the series of articles dealing with the servicing of standard receivers and the following makes are dealt with :—

Lotus
Kolster-Brandes
Gecophone
His Master's Voice
Consolidated Radio

In addition there are articles dealing with the servicing of well-known makes of electric gramophone motors and automatic record changers.

The important subjects of "Wireless Theory" and "Wireless Mathematics" have been carried to a conclusion in this volume, and there can be little doubt that reade s will find these two sections of the work not only useful but also highly interesting, thanks to the care which has been given by their respective authors to the difficult problem of presenting these subjects in a clear, sound and also attractive manner.

Tested circuits and useful charts and tables and a comprehensive glossary, the latter compiled by Mr. Ralph Stranger, make a fitting conclusion to what is, we believe, the most comprehensive practical treatise on broadcast wireless reception yet available.

E.M.

CONTENTS

COMPLETE WIRELESS

A PRACTICAL AND AUTHORITATIVE WORK FOR EVERYONE INTERESTED IN THE WIRELESS INDUSTRY

General Editor :
EDWARD MOLLOY

Advisory Editor :
RALPH STRANGER

VOL. I

Contributors to Vol. I :

S. R. MULLARD, M.I.E.E.
L. McMICHAEL, A.M.I.E.E.
L. D. MACGREGOR
H. E. J. BUTLER
R. C. WALKER, B.Sc.
J. H. A. WHITEHOUSE
L. H. FITZ-GIBBON
C. H. HAYWARD
E. W. HOBBS, A.I.N.A.
NOEL ASHBRIDGE, B.Sc., Chief Engineer, B.B.C.
RALPH STRANGER
W. F. FLOYD, B.Sc. (Lond.)
H. W. JOHNSON
HARLEY CARTER
JAMES H. BOOT
H. H. DOWSETT
A. PINK
FRANK PRESTON, F.R.A.

GEORGE NEWNES LIMITED
SOUTHAMPTON STREET, LONDON, W.C.2

Index and Classified Key enabling all articles on any particular subject to be readily turned up will be found at the end of the Complete Work.

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD., LONDON AND TONBRIDGE.

PREFACE TO VOL. I

THIS volume contains much to interest everyone in the Radio Industry as well as enthusiastic amateurs. Two items of outstanding interest are the series of articles which deal respectively with " Wireless Theory Made Plain " and " Servicing of Standard Sets."

The first mentioned series has been written by the Advisory Editor, Mr. Ralph Stranger. Mr. Stranger is already well known for his articles which have appeared in serial form in *World Radio*, and also for his books which have been issued under the title of " Ralph Stranger's Wireless Library." A feature which renders these articles of special value is the fact that the author has throughout based all his explanations upon the most modern theories which regard the electric current as a flow of electrons from the negative to the positive. Even those readers who are familiar with the older text-books dealing with electrical theory will find much to interest them in Ralph Stranger's lucid exposition of the subject. The photographs used to illustrate theoretical principles are also worthy of special attention.

The second series deals with the Servicing of the following standard makes of wireless receivers :—

Ekco
Pye
His Master's Voice
Edison Bell.

It is obvious that no one man could be expert on every type of receiver. Therefore, for the compilation of these articles we arranged to have each written by a technical expert attached to the firm responsible for the design and manufacture of the particular set dealt with. This, coupled with the fact that skilled photographers have been employed to secure pictures illustrating practical methods of dismantling and adjusting, has enabled us to produce a series which forms a valuable addition to existing wireless literature.

We leave the reader to look through the pages of the present volume, where he will find scores of other items which will provide him with hours of informative and instructive reading.

E. M.

CONTENTS

CONSTRUCTION — EXPERIMENTAL — THEORY

NEWNES COMPLETE WIRELESS

FREE CHART
FOR
DOUBLE CONE
PORTABLE
INSIDE

WIRELESS
THEORY AND
CONSTRUCTION
MADE PLAIN

1/-

Part 1

IN ABOUT 24 WEEKLY PARTS

COMPLETE WIRELESS

FOREWORD

THE progress in wireless practice during the past few years has been enormous. The Screened Grid, the Pentode, the Bi Grid and the Variable-Mu Valves have made their appearance in rapid succession. Band Pass Tuning, Push-Pull Amplification, the Stenode, the Autotone, the Dual Speaker are other items which were unknown to the wireless industry a few years ago.

Here is a work designed to bring you right up to date on the theory, design and construction. Every article is sound, and the greatest care has been taken to ensure that every article can be readily understood.

Wireless is a development of electrical engineering. Therefore, to get a sound understanding of wireless, one must get a working knowledge of electrical principles.

In the low-tension circuit is used current of the order of half an ampere at a pressure of 2 volts. In the output circuit, from 10 to 100 milliamps. at a pressure of 60 to 150 volts is required. The supply of a mains-driven set may be 220 volts at 50 cycles, or 110 volts D.C. The voltages induced in the aerial-earth circuit are of the order of 2 to 20 millionths of a volt at a frequency of from 100 to 1,000 kilocycles on medium wavelengths, and up to 30,000 kilocycles on the very short wavelengths.

Again, for charging low-tension batteries, one may have to use mains transformers, valve rectifiers, Westinghouse rectifiers, or, on a larger scale, motor generators, charging panels and accessories.

To feel at home amongst such a variety of electrical appliances the modern wireless man must have a thorough grounding in electrical theory. A rule-of-thumb knowledge will suffice for the man who only wishes to construct an occasional set, but for the man who takes a pride in doing a thing well a good foundation of knowledge is indispensable.

This point has been kept well in mind in the compilation of the present work. No effort has been spared to make the theoretical treatment complete. In order to do this in a way which will be most useful to every reader, the subject has been developed from the simplest beginnings and has been illustrated by means of a specially planned series of photographs, which show laboratory experiments—some well known, some quite new.

In this way the reader who has not had the benefit of a regular course of training in a technical school or university can see being performed the experiments which he would have to make in order to get a practical knowledge of theoretical principles.

The staging of the photographs used in each theory article has cost many pounds, but it is believed that readers will appreciate the trouble which has been taken, because by this means they are enabled to visualise the experiments just as well as if they had the actual apparatus on the table before them.

Another important branch of the work is that of Design, or Theory applied to practice. Here we have been fortunate in securing the services of experimental and design engineers connected with some of the most famous wireless manufacturers. Readers will thus obtain the best advice to-day available in the industry.

Set construction, though of less importance now than in the early days of broadcasting, is still of very wide interest. We have, therefore, included in this work many proved circuits and designs together with full details of the methods of construction and wiring.

In place of the usual blue print we are adopting a novel Uni-view Wiring Diagram which shows the layout of the components on baseboard and panel, and complete wiring arrangement in a single view.

A growing number of the public prefer to purchase a well-known make of receiver and radiogram. We realise, therefore, that the man interested in present-day wireless is often called upon to adjust, repair, or " service " one or other of the well-known makes.

For this reason we have included in this work many articles devoted to the servicing of high-class receivers and radiograms. Needless to say, this has only been rendered possible by the co-operation of the makers concerned. We take this opportunity of expressing our appreciation of this invaluable help.

In conclusion, we hope that the wealth of information which has been brought together in this work will be of real use both to the enthusiastic wireless amateur and to the man to whom " wireless " is bread and butter.

R.S.
E.M.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION I—CURRENT ELECTRICITY

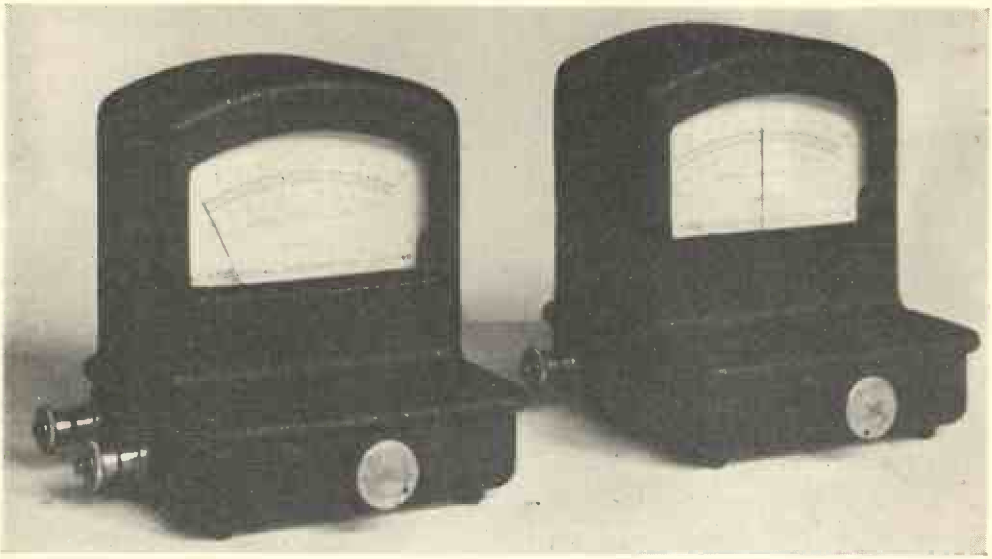


Fig. 1.—INSTRUMENTS TO BE USED IN THE FOLLOWING EXPERIMENTS.

As we cannot see electricity, it is necessary to use instruments which show what is happening in an electrical circuit. Above are shown two such instruments which will be used in the experiments which follow. The instrument on the right has a centre zero reading, and will indicate when a current is flowing in either direction in the circuit to which it is connected. On the left is a similar instrument containing a rectifier. This instrument will indicate the presence of an alternating current which flows rapidly backwards and forwards through the circuit. Such a current would only make the needle of the first instrument quiver. Both instruments are extremely sensitive, and will indicate currents as low as *one-millionth of an ampere*. The instrument on the left can, for instance, be used to measure the extremely small currents which flow to and fro in a wireless aerial circuit.

SIR AMBROSE FLEMING recently told a story which will bear repetition. Here it is, in a condensed form.

SCHOOLMASTER: "What is electricity?"

SMALL BOY: "I did know, Sir, but I've forgotten."

SCHOOLMASTER: "What a pity! The only person who knew what electricity is, has forgotten!"

The true nature of electricity provides an interesting field for speculation, and the most up-to-date theory concerning it will be dealt with fully in a later article. In this first article it is proposed to show how an electric current can be produced and just a few of the things it will do.

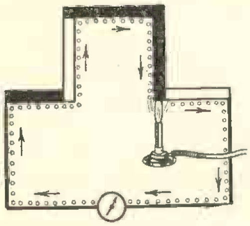


Fig. 2.—A SIMPLE METHOD OF OBTAINING A CURRENT OF ELECTRICITY.

If one junction of two different metals is heated, a current will flow from the junction with the higher temperature to the junction with the lower temperature. See also Fig. 3.

Electricity from Heat

The most direct method is by heating the junction of two *dissimilar* metals such as copper and constantan or bismuth and

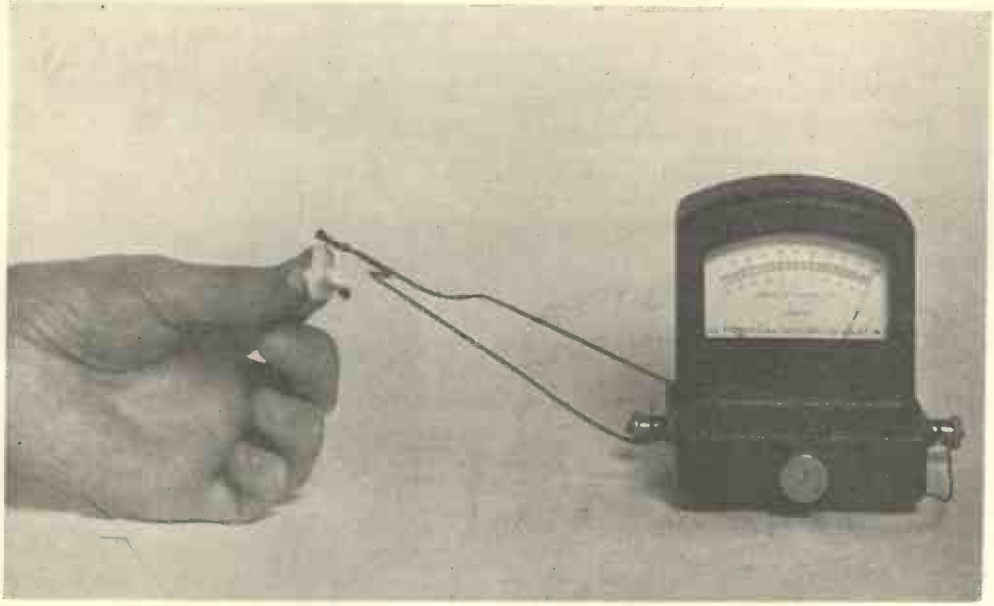


Fig. 3.—The Simplest Method of Generating Electricity by Heat.

In this picture the junction of two different metals—copper and iron—is being heated by the flame of a match. The other ends of the junction are connected to the meter, and it can be seen that quite an appreciable current is flowing in the circuit. The needle has moved over to the right.

antimony, as shown in Figs. 2 and 3. This appears to be a beautifully simple method of obtaining a current of electricity. And so it is, but when attempts have been made to construct an electric battery, using this principle, the results have not been satisfactory. It is found that the junctions of the metals soon become oxidised and ineffective if any attempt is made to obtain appreciable current from this source.

The above effect is called the *Thermo-Electric effect*, and the junctions used are called *Thermo-junctions*. These are used successfully in electrical thermometers, and also in very delicate measuring instruments, *i.e.*, for measuring current in a wireless aerial.

A DIGRESSION

Electrons and Protons

An atom represents a miniature solar system in which the place of the sun is taken by a *nucleus* and the planets are replaced by rotating *electrons*.

In the nucleus are to be found two different particles of pure electricity: electrons (particles of negative electricity) and *protons* (particles of positive electricity). The electrons in the nucleus are known as "cementing electrons." In every atom there are as many electrons as there are protons, and while all the protons are concentrated in the nucleus, the electrons are both inside the nucleus and outside. It is the outside rotating or "planetary" electrons that are responsible for all the electric phenomena.

When an atom has its natural equal numbers of electrons and protons it is said to be normal or *neutral*. But should an atom lose or gain some planetary electrons it starts exhibiting abnormal properties and is said to be *electrified*.

Thus electrification merely means a surplus or deficit of planetary electrons in the atom.

Protons Attract Electrons

The reason for this is that *protons attract electrons*. It is the unlike that attract, the like repel. An electron will repel another electron, just as a proton will repel a proton. As the number of electrons and protons is always equal in a normal atom, the forces within the atom are balanced. Should a "planetary" electron pass on to another atom a proton in the deserted atom will remain unbalanced. It will attract any electron passing near the atom.

When a stray electron gets into a strange atom the local "planetary" electrons will try to repel it. This enables us to cause a migration of electrons from atom to atom by causing a surplus of electrons at one point and a scarcity of electrons at another point.

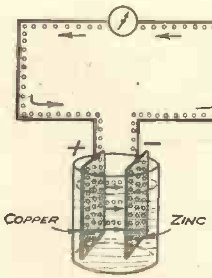


Fig. 4.—A SIMPLE ELECTRIC CELL.

Electrons flow from the negative side of a cell to its positive side.

We shall consider the electron and proton later on, and in the meantime make our acquaintance with another method of generating electrical currents.

The Simple Electric Cell

Another method is to immerse plates of two different metals, such as zinc and copper, in a vessel filled with dilute sulphuric acid forming what is known as a *primary* cell. When the zinc and the copper are connected through a wire we shall find that a current will flow through the wire all the time the cell is in circuit. The acid molecules will attack the copper and rob its atoms of some of their electrons. Having accomplished this robbery they will retire with the proceeds to the zinc and make it rich in electrons. Thus, the copper will be poor in electrons and the zinc rich in electrons, as far as the outside circuit is concerned. The copper wanting its electrons back will start borrowing electrons from the atoms of the wire. The atoms of the wire which have been robbed of their electrons will borrow from the atoms next to them, and so an exchange will be carried on till the atoms at the opposite end of the wire will supply their deficiency of free electronic particles from the zinc which is rich in electrons. In this manner, as fast as the acid is robbing copper of its electrons, the copper will be compensating its deficiency from the connecting wire and the latter from the zinc.

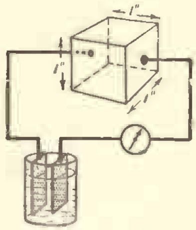


Fig. 5.—MEASURING THE RESISTIVITY OF VARIOUS MATERIALS.

An Electric Current is a Flow of Electrons

This will maintain a constant stream of electrons flowing from the zinc, through the outside wire to copper and from copper to zinc inside the cell. A complete circuit is thus formed. It should be clearly understood that a single electron starting from the zinc will not go right through the wire to the other end. It will merely jump into the sphere of action of the first wire atom, kicking out in the process one of the electrons of that atom. The latter, coming into the sphere of action of the second atom, will eject another electron, which will eject a third, and so on.

Since an end of a wire represents millions upon millions of atoms, it is clear that millions of electrons will be thus migrating at once. The more electrons are taking part in the flow the stronger is the current through the wire.

Electromotive Force

It is easily realised that these migrating electrons have to cope with the repelling forces of the planetary electrons in the atoms of the conductor. They are migrating under the influence of a permanent difference of potential, which means that there are at the ends of the circuit different numbers of electrons per atom (one end is rich in electrons and the other end is poor in electrons). The exposed protons at one end are exercising an

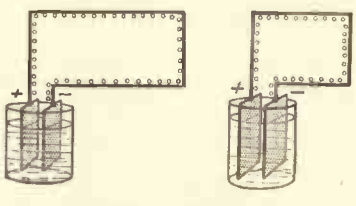


Fig. 5A.—MORE ELECTRONS WILL FLOW THROUGH A SHORT WIRE THAN THROUGH A LONG WIRE CONNECTED ACROSS THE SAME CELL.

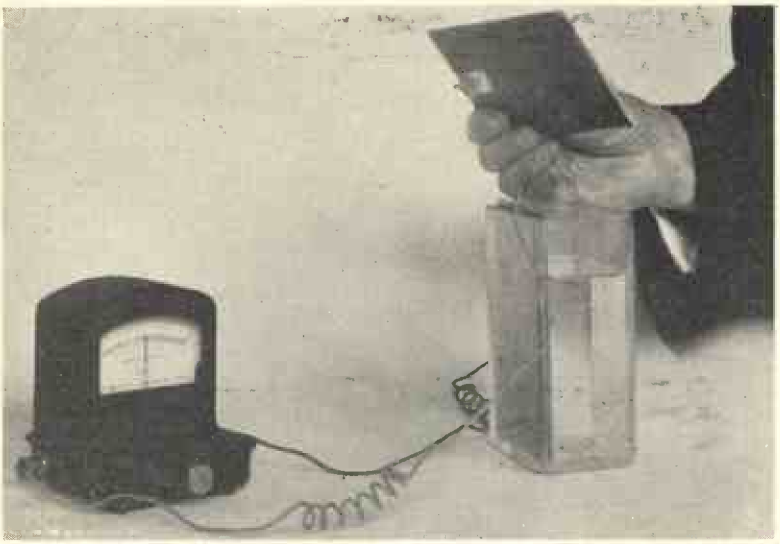
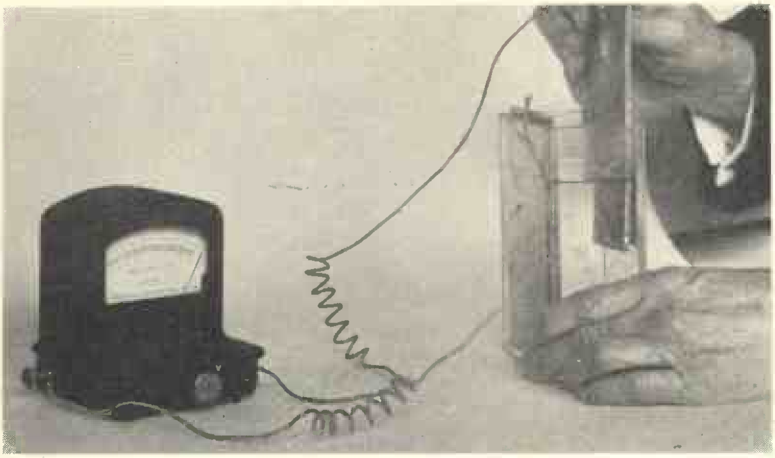


Fig. 6 (LEFT). — THE ELECTRIC BATTERY IN ITS SIMPLEST FORM.

Here we see a glass jar containing weak acid. Wires from the indicator are connected one to a copper plate resting in the jar, and the other to a zinc plate held above the jar. Note that no current is flowing in the circuit.

Fig. 6A (RIGHT).— THE ELECTRIC BATTERY IN ITS SIMPLEST FORM.

The zinc plate has now been placed in the acid completing the circuit. Electrons are flowing from the copper to the zinc plate inside the battery and from the zinc plate to the copper plate in the outside circuit. This forms an electric current, which is shown on the instrument.



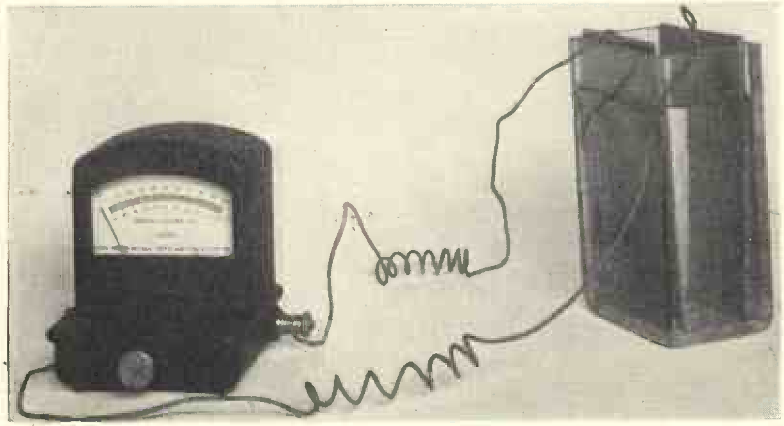


Fig. 6B (LEFT).— THE ELECTRIC BATTERY IN ITS SIMPLEST FORM.

In this experiment the connections of the battery have been reversed. Note that current is now flowing in the opposite direction as shown by the needle of the indicator.

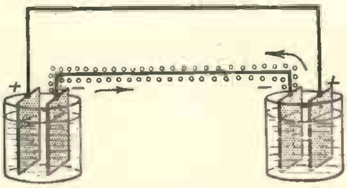


Fig. 7.—Two Equal Currents Flowing in the Opposite Directions Neutralise Each Other.

There is no current flowing in the circuit.

attractive force upon the electrons in the atoms lying close to them and thus indirectly upon the electrons in surplus at the other end. It is this force that is responsible for driving the electrons round the circuit. For this reason we call it an *electromotive force, i.e.*, a force which moves electricity.

Each cell consisting of two different metals immersed in diluted sulphuric acid represents a definite difference of potential between its two plates. Such cells can be added in such a way that their potential differences will also add (the potential difference of a cell does not depend on the size of the plates but only on the materials used). In this way larger and larger electromotive forces can be applied to the circuit. Other things being equal, the larger the E.M.F. the larger is the flow of electrons, *i.e.*, the larger is the current. But the planetary electrons in the atoms of the conductor limit the flow. They oppose the migrating electrons and to some extent stop some of them from passing.

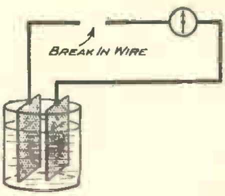


Fig. 8.—A Dis.
No current is flowing.

Electrical Resistance

For this reason we say that each conductor offers a certain amount of *resistance* to the flow of electric current. If we take a cubic inch of a number of materials and measure the flow of current between two opposite faces under the influence of the same electromotive force, we shall find that each material will offer a resistance of its own per unit volume. This *specific resistance* per unit volume on the part of each material is called the *resistivity* of the material. The reason for the existence of resistivity is that every material has a different number of planetary electrons per atom, and so their influence differs.

The Longer the Wire, and the Thinner the Wire, the Greater the Resistance

Apart from resistivity, it is found that the resistance of a conductor increases with the length of the conductor (the migrating electrons have to cope with the combined repelling force of all the planetary electrons throughout the length), and also increases as the thickness of the conductor decreases. The thinner the conductor the greater the resistance. This is due to the fact that too many migrating electrons try to squeeze in within a very narrow channel.

How Temperature affects Resistance

The resistance of a conductor also increases as the temperature of the conductor increases. In this case the rate of molecular vibration is increased, the atoms become more energetic and the planetary electrons are also more active and whirl round more rapidly. In this manner they are close to the migrating electrons more often in each revolution around the nucleus than in the case of a colder conductor.

Professor Ohm's Discovery

Thus it is clear that both the E.M.F. and the resistance of the conductors in the circuit regulate the strength of the current in the circuit. Professor Ohm found that there is a definite relation between these three items. Starting with one cell he investigated the strength of current with longer and longer conductors, and he found that the current strength diminished as the conductor became longer and longer. Then he took a definite length of a conductor and started using more and more cells and discovered that with a given resistance as the E. M. F. increased the current increased. There were no other items to

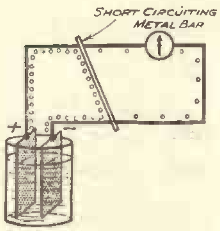


Fig. 9.—Electrons Short-circuited.

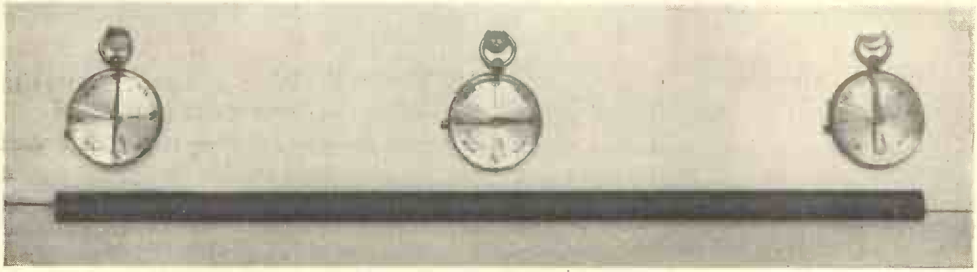


Fig. 10.—A Permanent Magnet.

Three small compasses have been used to show the magnetic condition of this steel bar. Note that one end of the bar attracts the north pole of the compass (this is the south pole of the magnet) whilst the other end attracts the south pole of the compass. The centre of the magnet does not attract the compass needle. Note that the " strongest " parts of the magnet are about ¾ inch from the ends of each pole, as can be seen from the positions of the compass needles.

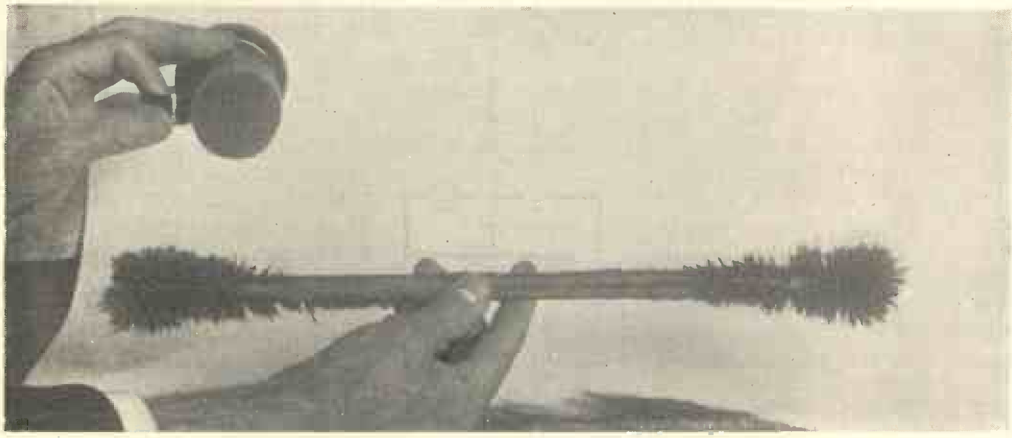


Fig. 11.—A Permanent Magnet.

Here is another method of showing how the magnetism is distributed in the magnet. Iron filings have been sprinkled over the magnet. Note that the filings are thickest round the poles, whilst the centre is almost bare of filings.

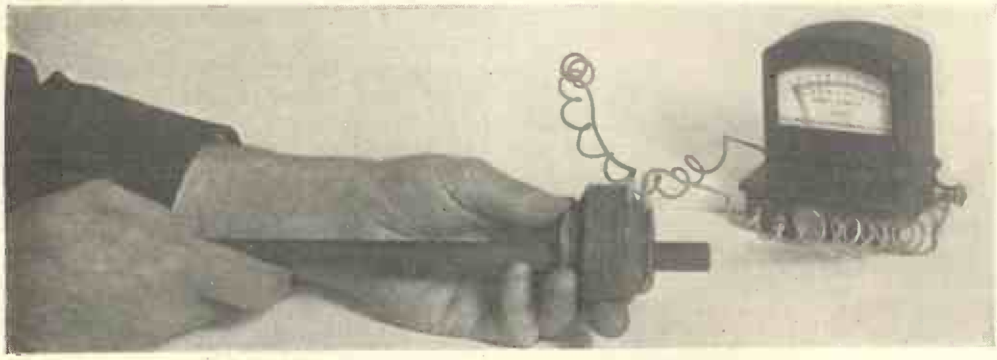


Fig. 12.—A Simple but very Important Experiment.

In the above picture we see the permanent magnet being thrust into the centre of a coil of wire ; the ends of which are connected to our current indicator. Note that quite a strong current has been set up in the circuit. A very simple experiment, but one which illustrates the principle on which all electric dynamos, magnetos and similar generators are based. The current only flows whilst the magnet is actually moving.

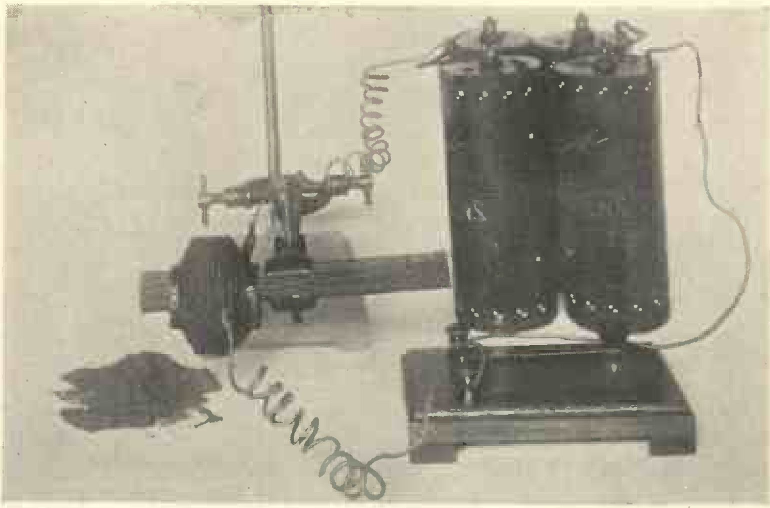


Fig. 13 (RIGHT).—THE SIMPLEST FORM OF ELECTRO-MAGNET.

The apparatus consists of a bundle of soft iron wire with a coil slipped over one end. The coil is connected to a battery through a switch which is here shown open. Note that the iron core does not attract the filings underneath.

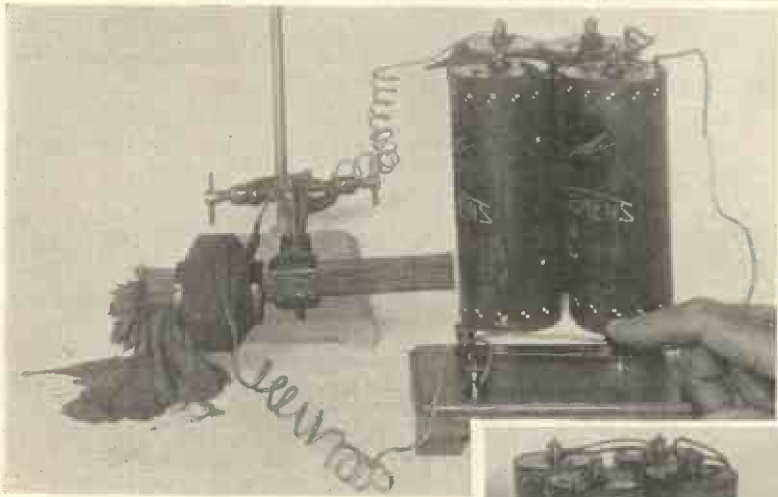


Fig. 14 (LEFT).—THE SIMPLEST FORM OF ELECTRO-MAGNET.

As soon as the switch is closed a current flows round the coil and the iron core becomes strongly magnetised, as can be seen by the iron filings now clinging to it.

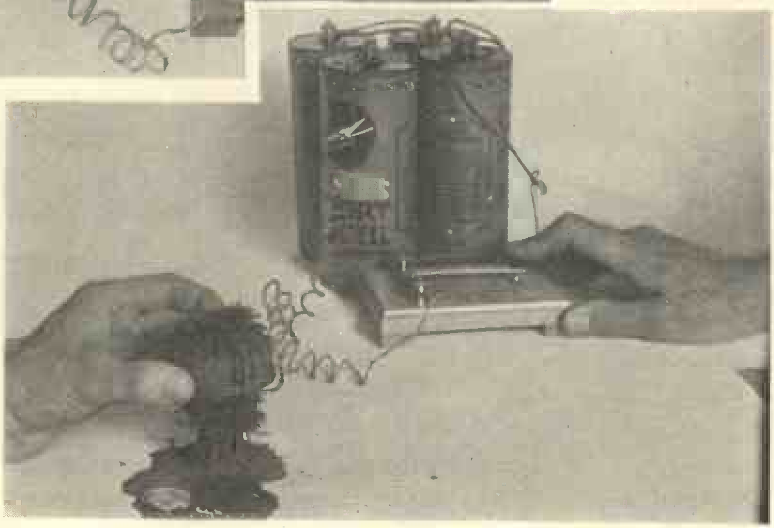


Fig. 15. — AN ELECTROMAGNET WITHOUT A CORE.

In this picture it can be seen that a coil of wire carrying an electric current will behave as an electromagnet even though it has no core of iron through the centre. The iron filings have been drawn up into the centre of the coil. The inclusion of an iron core strengthens the magnetic effect considerably.

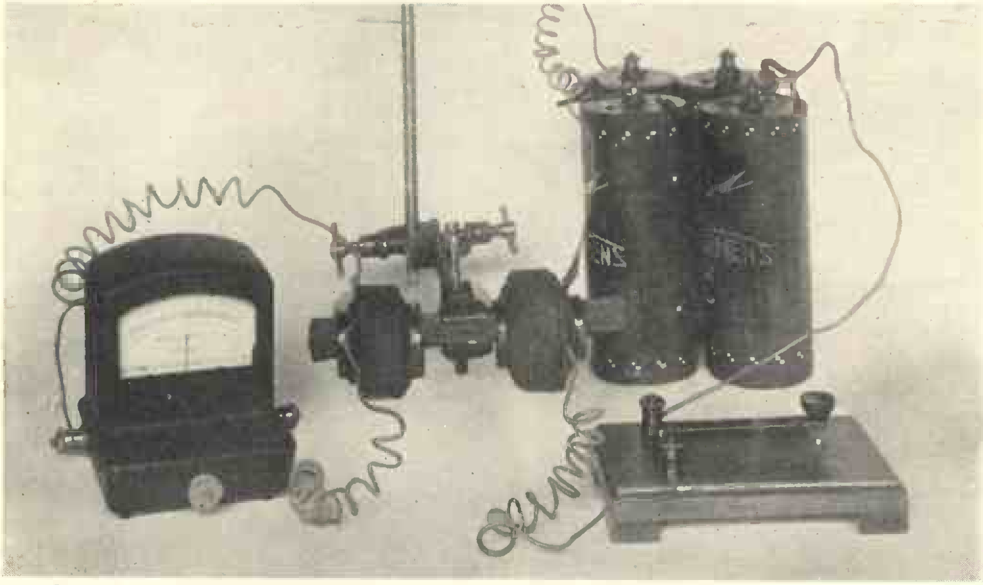


Fig. 16.—THE PRINCIPLE OF THE IRON CORE TRANSFORMER.

Here we see two coils mounted on the soft iron core. One coil is connected to a battery and switch. The other coil is connected to the indicator. Note that with the switch open no current is flowing in either circuit. This shows in simple form an iron core transformer with 1·1 ratio.

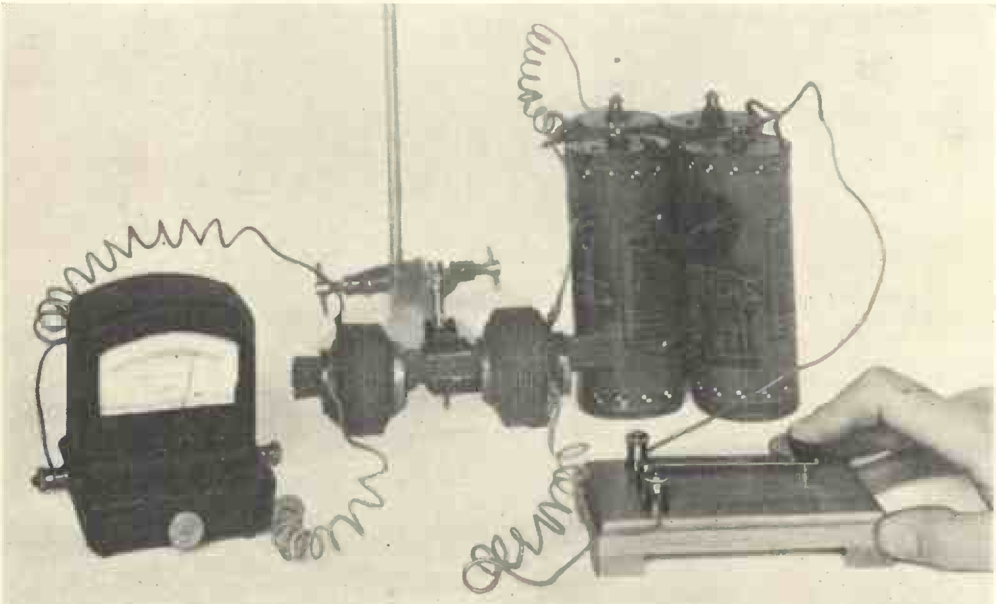


Fig. 17.—THE PRINCIPLE OF THE IRON CORE TRANSFORMER.

This photograph was taken as the switch was being closed. Note that a strong current is set up or induced in the second coil, at the instant of closing the switch. This is called induction.

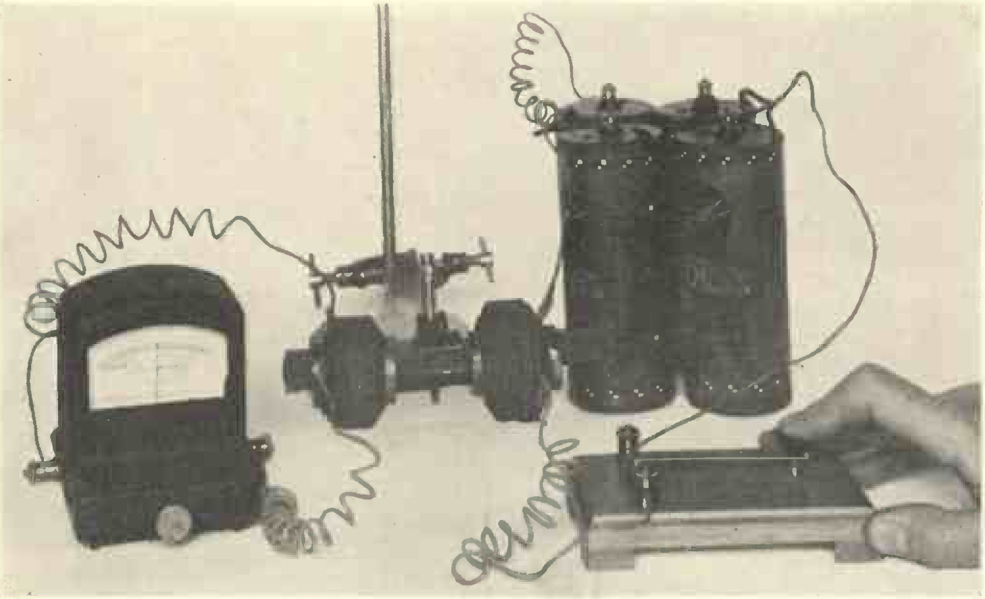


Fig. 18.—The Principle of the Iron Core Transformer.

This photograph was taken 30 seconds after the previous one. Although the current is still flowing through the first coil, no current is now flowing through the second coil, as the needle is now in the zero position. Induction only occurs whilst the magnetic conditions are changing.

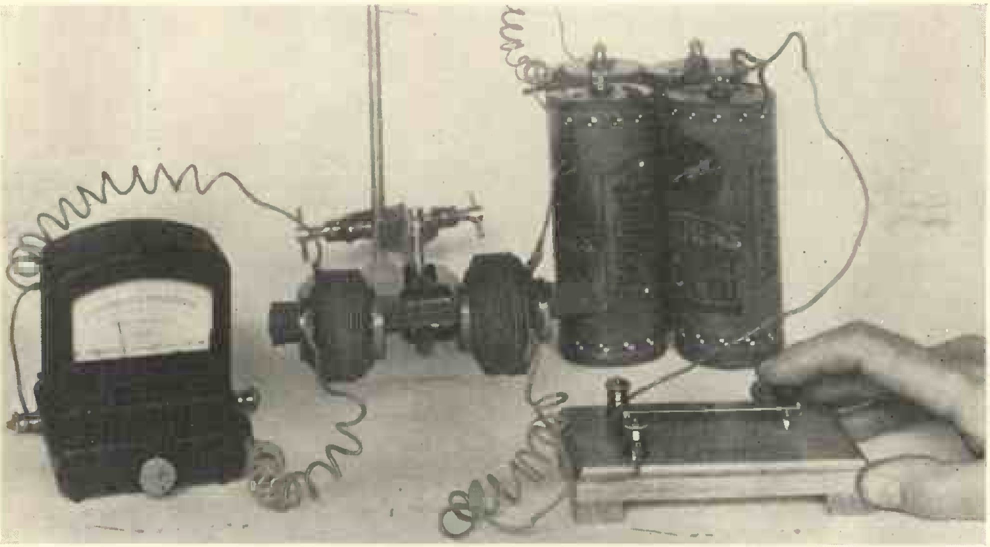


Fig. 19.—The Principle of the Iron Core Transformer.

This photograph was taken as the switch was being opened. Notice that a current has been induced in the second coil in the opposite direction from that shown in Fig. 17. In the above simple apparatus the coil on the right can be taken as the primary of the transformer and the coil on the left as the secondary. We can see from the above experiments that (*a*) when the current is growing in a primary it sets up a sympathetic current in the secondary, (*b*) a steady current flowing in the primary produces no effect in the secondary, (*c*) when the current is dying away in the primary this sets up a sympathetic current in the secondary.

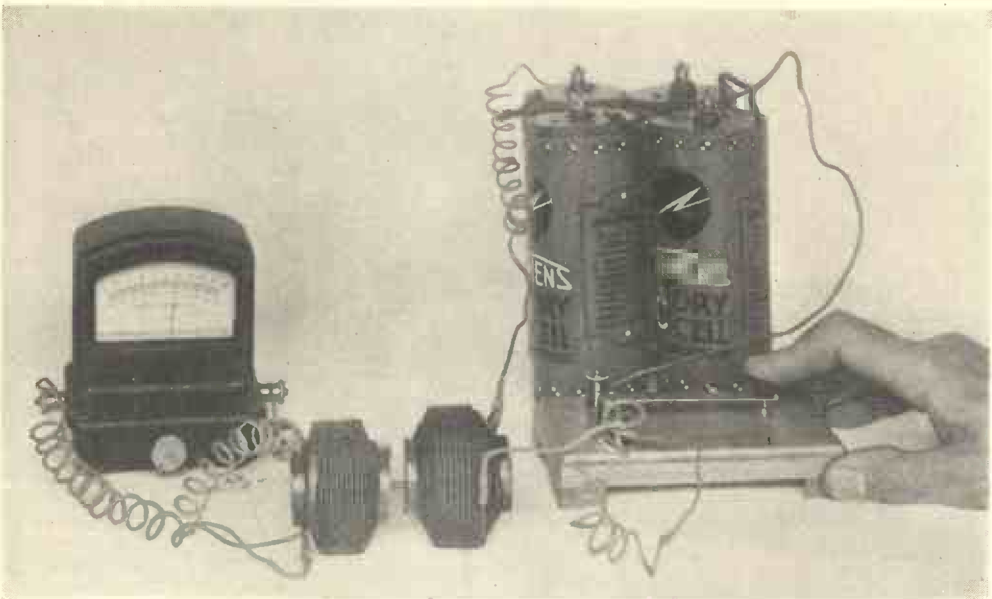


Fig. 20.—THE AIR CORE TRANSFORMER.

The two experiments in Figs. 20 and 20A show that the induction effect between the two coils is still obtainable even without the iron core, although it is very much less. Note that in the second picture one coil has been reversed—thus causing the induced current to flow in the opposite direction.

consider, so that he defined a law as follows :—

$$\text{current strength} = \frac{\text{E.M.F.}}{\text{resistance}}$$

$$\text{also resistance} = \frac{\text{E.M.F.}}{\text{current}}$$

$$\text{and, finally, E.M.F.} = \text{current} \times \text{resistance.}$$

This means that if we have an E.M.F. of 6 units and a resistance of 2 units the current strength is $\frac{6}{2}$ or 3 units. Similarly, if we have an E.M.F. of 10 units and a current of 5 units, the resistance is $\frac{10}{5}$ or 2 units.

Again, if we have a current of 7 units and a resistance of 5 units, the E.M.F. must be 7 × 5, or 35 units.

Open Circuit and Short Circuit

In order that a current should flow in the circuit we must have, in the first instance, the circuit itself, which should be an *uninterrupted chain of conductors* connected across some source of electromotive force. If the chain is broken at one place (this is called a dis, or open circuit) no current will flow in the circuit for obvious reasons. On the other hand, if another conductor is placed across some two points of the circuit, providing a short cut for the electrons, the majority of them will take the short cut and only very few electrons will flow through the rest of the circuit. Such a state of affairs is called a *short circuit* (a short). Be it a dis or a short, the electrons will not take the intended route and the apparatus included in the circuit will fail to function.

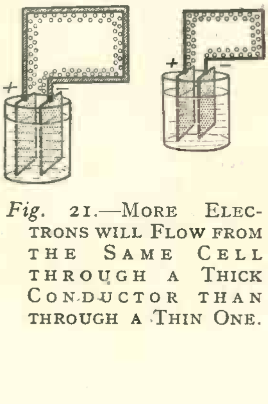


Fig. 21.—MORE ELECTRONS WILL FLOW FROM THE SAME CELL THROUGH A THICK CONDUCTOR THAN THROUGH A THIN ONE.

Branched Circuits

The short circuit brings us to another type of circuit, and that is the divided circuit. Very often it is necessary to have a number of branched circuits. The electrons will divide into a number

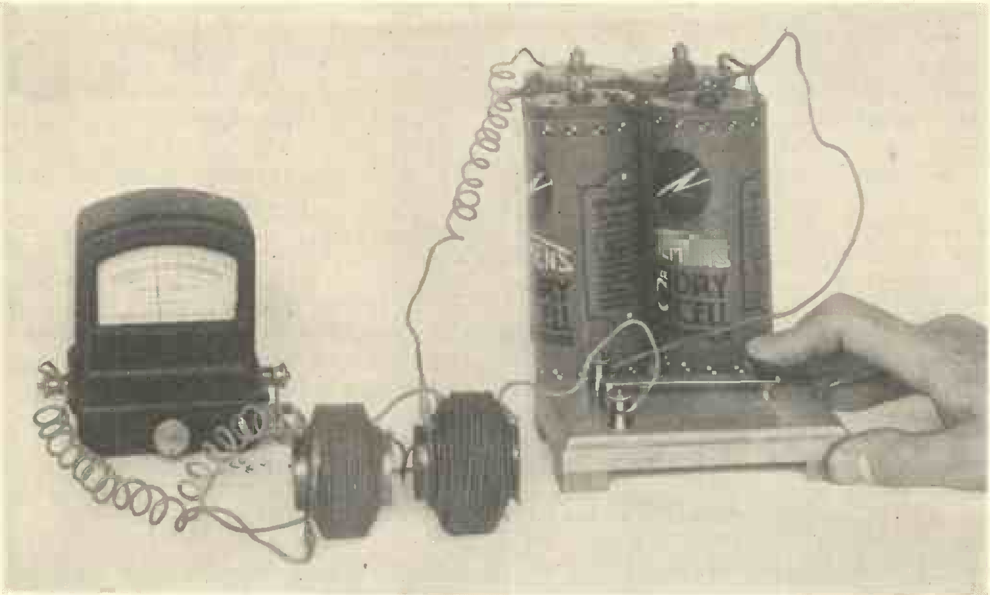


Fig. 20A.—THE AIR CORE TRANSFORMER.

In this picture one coil has been reversed, thus causing current induced when the circuit is completed in the first coil to flow in the opposite direction through the second coil.

of groups at the cross-roads, a number of them travelling through each branch. The number of electrons in each branch will depend upon the resistance offered by this branch. The greater the resistance the smaller the current. It is clear that the number of migrating electrons through the main circuit, outside the branches, will be equal to the sum of the number of electrons passing in each branch.

Opposed Currents and E.M.F.'s

If, for some reason or other, two equal crowds of electrons are travelling through the same conductor, but in opposite directions, they will stop each other from going through and there will be no current at all. If two unequal crowds are migrating in opposite directions at the same time, the larger crowd will prevail, and while equal numbers of electrons are stopping each other, the balance of the larger crowd will go through. Thus, the final or, as we say, *resultant current* will be equal to the difference of the two. Similarly, if two E.M.F.'s are acting in the opposite directions, *i.e.*, one against the other, if they are equal in magnitude, the net E.M.F. will be *nil*, and there will be no current flowing. If one E.M.F. is larger than the other the resultant E.M.F. will be the difference of the two.

Current flows from Negative to Positive

In the case when the E.M.F. is supplied by a cell, the current in the circuit is flowing always in the same direction from the plate rich in electrons (negative plate) to the plate poor in electrons (positive plate). Or, as it is usually stated, *the current flows from the negative terminal of the cell to its positive terminal.* The text-books will differ from us on this point, but they have been written without taking the electronic theory into consideration.

Apart from the

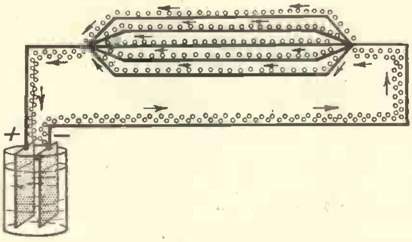


Fig. 22.—HOW CURRENT BRANCHES OFF.

direction of flow it is found that with a given cell E.M.F. and given resistance the strength of the current is always the same. Such a current always flowing in the same direction, and always at the same magnitude, is known as *direct current,* abbreviated as D.C. in order to distinguish it from the so-called *alternating current* (A.C.). The latter will be fully explained later.

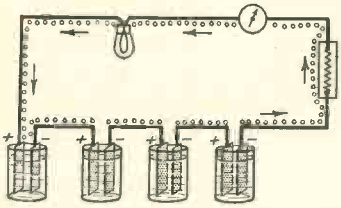


Fig. 23.—An Electrical Circuit Lighting a Lamp Filament.

Other methods of producing an electromotive force by moving a coil of wire across the poles of a magnet, and also by magnetising and demagnetising an iron bar on which a coil is mounted, are illustrated in Figs. 12 to 19.

These will be dealt with more fully in later articles, but for the moment it may be remarked that the simple experiments here illustrated show the principles on which the L.F. transformer and H.F. transformer depend.

QUESTIONS AND ANSWERS

What is an Electric Current ?

A flow of electrons along a wire or other conductor.

What is an Electromotive Force (E.M.F.) ?

That which produces or tends to produce a flow of current in a circuit. It is measured in volts.

How are E.M.F. and Current Related ?

The current (amperes) in a circuit is equal to the E.M.F. (volts) divided by the total resistance of the circuit (ohms).

What Determines the Resistance of a Wire ?

First the material of which it is made ; second, the length ; third, the cross-sectional area.

Thus a copper wire has a lower resistance than an iron wire of the same length.

A wire 20 feet long has twice the resistance of a similar wire 10 ft. long.

A wire 0·1 inch diameter has four times the resistance of a similar wire which is 0·2 inches diameter.

Which Plate forms the Positive of a Simple Cell ?

The copper plate.

Which Way do the Electrons Flow in a Battery Circuit ?

From the negative to the positive outside the battery, and from positive to negative inside the battery.

Name the Three Chief Effects of an Electric Current.

Heating (*e.g.*, in valve filaments), magnetic (*e.g.*, in transformers, telephones and loud speakers), chemical (*e.g.*, in charging a L.T. battery).

What is the Principle of an Iron Core Transformer ?

In its simplest form, two coils are wound on an iron core. A varying or alternating current supplied to one coil (the primary) produces a varying magnetic effect in the core. This generates or induces a varying current in the second coil (the secondary), although there is no electrical connection between the two coils.

What are the Two Kinds of Electric Current and how are they Subdivided ?

Direct Current.—Subdivided into steady and intermittent. *Alternating Current.*—Subdivided into low (or mains) frequency, audio (or speech) frequency and high (or radio) frequency.

MAINS TRANSFORMER CONSTRUCTION

By L. D. MACGREGOR

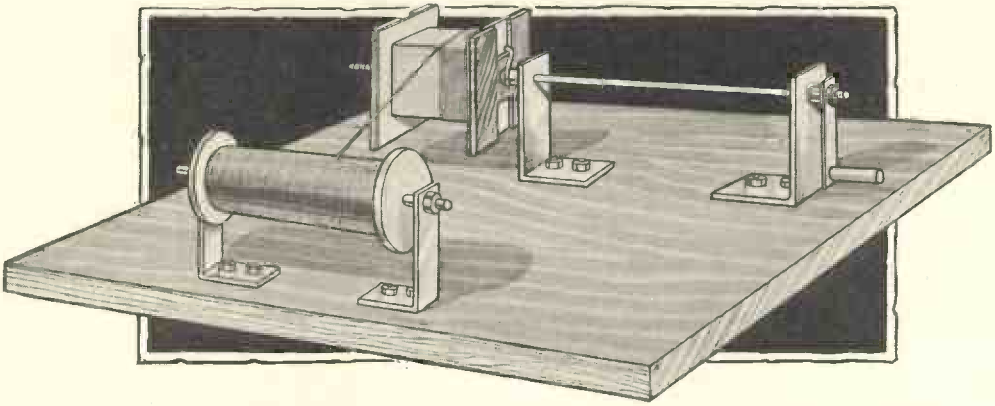


Fig. 1.—Showing a simple Winding Machine and Reel Carrier rigged up for winding a Mains Transformer.

IN this article will be found full details and working instructions for the construction of a mains transformer capable of delivering an adequate output to meet the requirements of the average wireless receiver.

What the Transformer will do.

The transformer described here has been designed to work from 200 to 240-volt mains at from 40 to 60 cycles. It will, when used with the valve with which it was tested, deliver an output of 260 volts at 60 milliamps., together with an output of 4 volts at 3 to 4 amps. for filament supply to A.C. valves. The consumption from the mains is of the order of 40 watts and the efficiency is well over 80 per cent. In Table I particulars of the windings are given, while Table II gives particulars for winding the primary to suit other mains voltages than that covered by the construction described herein.

MATERIALS REQUIRED FOR THE TRANSFORMER

Wire

* 9 oz. of 28 S.W.G. double silk-covered copper wire.

$\frac{1}{4}$ lb. of 38 S.W.G. double silk-covered copper wire.

† $\frac{1}{4}$ lb. of 18 S.W.G. double silk-covered copper wire.

† $\frac{1}{4}$ lb. of 16 S.W.G. double silk-covered copper wire.

Insulation

Insulating sleeving (" Systoflex ").

2 lengths of 1 mm. sleeving.

2 lengths of 2 mm. sleeving.

4 pieces of Empire Cloth (approx. 2 feet by $2\frac{3}{8}$ inches wide).

2 strips of oiled silk (approx. 2 feet by $2\frac{3}{8}$ inches wide).

One bobbin to take No. 4 " Stalloy " stampings, having a core space of 1 inch by $1\frac{1}{2}$ inches (Sound Sales, Ltd.).

" Stalloy " No. 4 Stampings (0·015 inch thick) to take a depth of $1\frac{1}{2}$ inches. Approximately 100 stampings.

One set of clamps to hold core (Sound Sales, Ltd.).

Some strong thread or fine twine.

White tape, $\frac{1}{4}$ inch or $\frac{3}{8}$ inch wide.

The quantity of wire shown in this list was that actually used on this transformer, and the novice is advised to purchase slightly in excess of this amount to allow for wastage, etc.

* Primary Winding Wire. This will vary according to Mains Voltage (see Table II).

† Good Enamelled Wire may be used.

CONSTRUCTING A WINDING MACHINE

A simple winding machine (Fig. 1) can be easily constructed by anyone having the necessary tools and materials, and consists essentially of two brass or iron angle brackets, $3\frac{1}{2}$ inches high, 1 inch wide by $\frac{1}{8}$ inch thick, having a foot of $1\frac{1}{2}$ to 2 inches long drilled to receive the bolts which secure them to the wooden baseboard. The baseboard should be at least $\frac{3}{8}$-inch thick, and a convenient size is 16 by 9 inches.

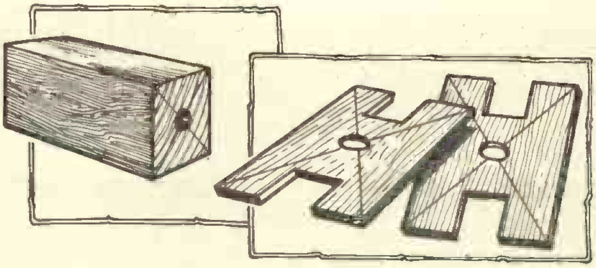


Fig. 2.—Wooden Supports for Winding the Bobbin.

Block of wood on left fits the bobbin core. On the right are the side supports of plywood for bobbin flanges during winding.

The Uprights

The uprights are drilled to take $\frac{1}{4}$-inch brass or steel rod of 1-foot length, threaded either O.B.A. or $\frac{1}{4}$-inch Whitworth for $1\frac{1}{2}$ inches from one end and $4\frac{1}{2}$ inches from the other end.

The threaded portion will project from the outer sides of the brackets when assembled, and a nut each side with a lock-nut will secure the spindle. The centre of the spindle should be at least $2\frac{3}{4}$ inches above the baseboard.

The Handle

Should some form of handle not be readily obtainable, a home-made one can be easily constructed from a piece of brass or iron 2 inches long, $\frac{3}{8}$-inch wide and $\frac{1}{16}$-inch thick. A hole is drilled in one end to clear the spindle and it is soldered to an hexagonal nut. The other end is drilled and tapped to receive an inch-long 4 B.A. or $\frac{1}{4}$-inch Whitworth bolt, and the grip may be made from $\frac{1}{2}$-inch rod, $\frac{7}{8}$ inch long, drilled to clear the bolt and countersunk at one end to receive the head of the bolt. Any suitable hard material will do for the grip.

The handle is screwed on to the spindle and securely held by means of a lock nut.

The Reel Carrier

Two brackets of similar size to those employed in the construction of the winder are used for the reel carrier.

The rod is prevented from sliding to and fro by means of collars having a grub screw in them. Spindle centres should be over $2\frac{1}{2}$ inches from the baseboard.

Secure the winder and reel-carrier rigidly to the baseboard by means of nuts and bolts, and see to it that the spindles move freely in their bearings.

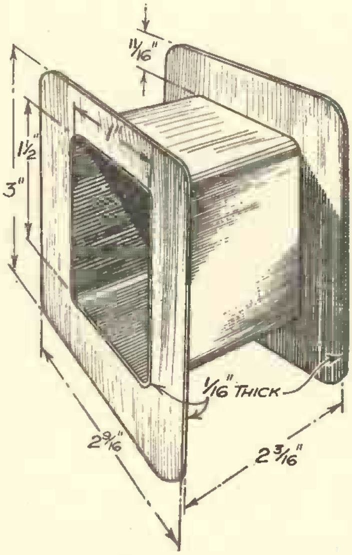


Fig. 3.—Bobbin, showing the Dimensions

LIST OF MATERIAL FOR WINDING MACHINE AND REEL CARRIER

Baseboard.—16 inches by 9 inches by $\frac{1}{2}$ inch (ply or hardwood).

4 *Brackets.*—$3\frac{1}{2}$ inches high by 1 inch by $\frac{1}{8}$ inch, having a foot $1\frac{1}{2}$ inches to 2 inches (brass or iron). (Strip metal, 1 inch by $\frac{1}{8}$ inch by 2 feet long will suffice for four brackets.)

1 *Spindle.*—1 foot long by $\frac{1}{4}$ inch, threaded O.B.A. or $\frac{1}{4}$-inch Whitworth for $4\frac{1}{2}$ inches from one end and $1\frac{1}{2}$ inches from other (brass or iron). 1 doz. hexagonal nuts (O.B.A. or $\frac{1}{4}$ inch Whitworth).

Table I

Particulars of Transformer described

Order of Winding.	Description.	Turns and Gauge of Wire.	Length of Winding (approx.)	Weight (approx.)	Resistance (approx.)
First	Primary winding, 240 volts.	1,440 turns, 28 D.S.C.	350 yds	9 oz.	40 ohms
	Tapped for 220 volts at	1,320 turns, 28 D.S.C.			
	Tapped for 200 volts at	1,200 turns, 28 D.S.C.			
Second .	½ secondary, 260 volts .	1,560 turns, 38 D.S.C.	700 yds.	¼ lb.	286 ohms
Third .	½ secondary, 260 volts .	1,560 turns, 38 D.S.C.			296 ohms
Fourth .	Rectifier filament winding, 4 volts.	25 turns, 18 D.S.C. or enamel.	8 yds.	¼ lb.	0·1 ohm
Fifth .	Filament supply for valves, 4 volts.	26 turns, 16 D.S.C. or enamel.	8 yds.	¼ lb.	0·056 ohm

Handle Material.—1 piece brass strip, 2 inches by ⅜ inch by $\frac{1}{16}$ inch; 1 piece rod, ⅞ inch by ½ inch (any hard material); 1 4 B.A. nut and bolt, 1 in. long; 1 doz. bolts and nuts for securing to baseboard.

1 *Spindle.*—¼ inch by 9 inches (brass or iron).

2 *Collars.*—¾ inch by ½ inch, drilled to clear ¼ inch and tapped for grub screws.

2 *Grub Screws.*

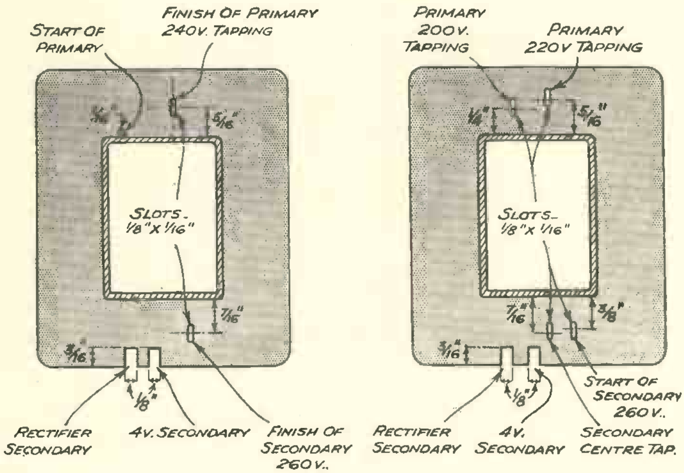


Fig. 4.—Positions of Slots in Bobbin Cheeks to take Leads from Windings.

MAKING WOODEN SUPPORTS FOR THE BOBBIN

Construct a block of wood of a suitable size (1 inch by 1½ inch by 2¼ inches) to fit the bobbin core and drill it down the centre so that it passes easily over the threaded rod of the winder (Fig. 2 (*a*)).

Cut two pieces of 3-ply wood to the same size as the bobbin cheeks and drill a $\frac{9}{32}$-inch hole in the centres. Then construct two slots ⅞ inch wide by ¾ inch deep in opposite smallest sides in order to allow the leads to pass freely when the bobbin is clamped between the wooden side supports (Fig. 2 (*b*)).

The object of these side supports is to counteract any tendency on the part of the bobbin to distort whilst winding is in progress. The wood block provides a secure means of turning the bobbin.

MAKING THE TRANSFORMER

Constructing the Bobbin

For those who are desirous of constructing their own bobbins, the sizes are given in Fig. 3, and suitable material is Paxolin or Bakelite. Unless considerable previous experience has been had in this direction it is advised that a ready-made bobbin be purchased.

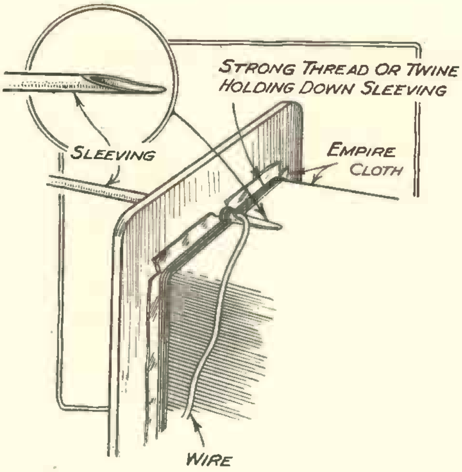


Fig. 5.—METHOD OF SECURING START AND FINISH OF WINDINGS.

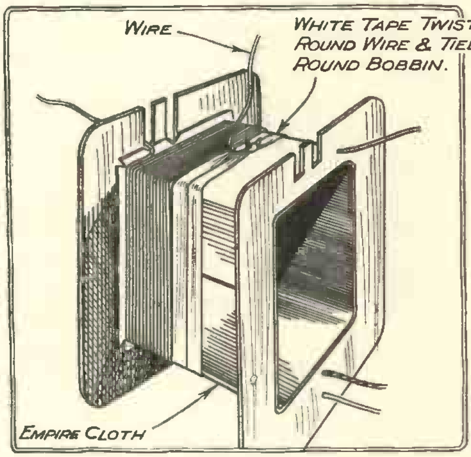


Fig. 6.—METHOD OF FIXING CENTRE TAPE ON 4-VOLT WINDING.

Preparing the Bobbin for Winding

The bobbin is prepared for winding by drilling the holes and cutting out the slots shown in Fig. 4. After this has been done all rough edges and projections should be removed with sandpaper and the bobbin smoothed down where necessary.

The bobbin next has the wooden block inserted in its core and the wooden end supports placed on either side and assembled on the spindle of the winder. Care is taken to see that the slots on the wooden end supports are opposite the drilled cheeks of the bobbin and the whole assembly is then locked on the spindle by means of clamping nuts. The reel of primary wire is fitted on its spindle and the spindle secured by means of the collars fitted with grub screws.

The First Layer

A piece of sleeving is cut at an angle and the wire threaded through it and allowed to project about 6 inches beyond sleeving. The sleeving is secured to the bobbin by means of strong thread or fine twine (Fig. 5). The most suitable knot for tying the sleeving is that known as the clove-hitch. The leads which come out from the bobbin should be secured and not be left free to rotate. The most satisfactory way of doing this is first to wind some paper round the projecting threaded spindle, then loosely wind the leads over it and secure with an elastic band. Although it is not practicable to wind the whole winding in even layers, it is definitely an advantage to do so with the first layer. Should the light be bad, place a strip of white paper beneath bobbin and between it and the reel. This will enable the wire to be seen more easily.

Starting the Primary Winding

The first winding, which is the primary, is made with No. 28 D.S.C. copper wire, and 1,200 turns are wound on. A tapping is taken here, and this may be done by looping the wire or by cutting it. Sleeving is used as before, and the winding is continued until 1,320 turns are wound on, when the second tapping is made and the process repeated until the full winding, 1,440 turns, is

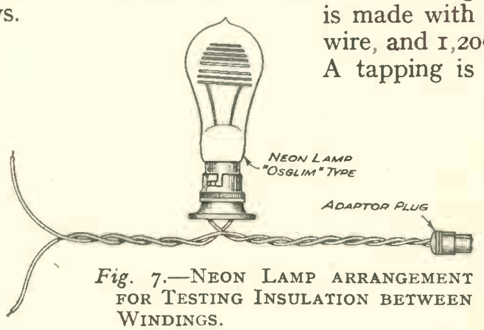


Fig. 7.—NEON LAMP ARRANGEMENT FOR TESTING INSULATION BETWEEN WINDINGS.

Lamp connected in series with mains between adjacent windings. If lamp glows insulation is faulty.

finished, care being taken to keep the winding as even and level as possible.

Insulating the Primary from the Secondary

The sleeving should be well secured before the insulation is put on. Then trim the Empire cloth to the width required. Two layers of Empire cloth are used for insulating the primary from the secondary, and the width should just exceed the winding width. If necessary the edge should be "frilled" by cutting along same so as to make a good fit against the cheeks. On no account should Empire cloth of just the exact width be used as, should the under winding be uneven, the upper winding is almost sure to slip past the insulation to the lower winding with disastrous consequences to the insulation. If the Empire cloth is fairly new it will be found to be sufficiently tacky to hold itself—otherwise it can be stuck down with Chatterton's compound.

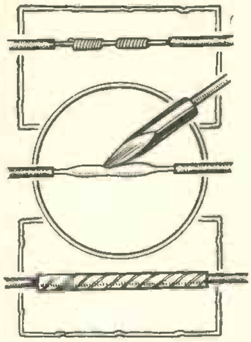


Fig. 8.—Method of Insulating Joints in the Winding.

First, each wire is twisted round the other. The wires are soldered, and then a piece of sleeving pulled over the joint and extending beyond it on each side.

Starting the Secondary Winding

Having replaced the reel of 28 D.S.C. with that of 38 D.S.C., the first half-secondary may be begun, the procedure being as for the previous winding, but in this case 1,560 turns are wound on and then the centre tap is brought out. After bringing the centre tap out, two layers of oiled silk are placed over the winding and the second half of the secondary, consisting of another 1,560 turns, is wound on. Another two layers of Empire cloth are now put on.

The Low Voltage Windings

The transformer is now ready for the low voltage windings. As these two windings are of fairly heavy gauge, it is advisable to rotate the bobbin by hand and to avoid kinks and keep the wire as straight as possible. Owing to the heavy gauge, tape is the most satisfactory material for securing the ends, and this should be twisted round the wire and then round the bobbin and knotted or otherwise secured (see Fig. 6).

Do not use unnecessary force when winding with heavy gauge wire or damage may ensue to the under layers.

The first winding is made with 18 D.S.C. copper wire and twenty-five turns are wound on, a tapping being taken from the thirteenth turn at the mid-point of the winding. A piece of flexible rubber-covered wire can be used for this tapping—the end is bared, cleaned, twisted round the 18 gauge wire, which has been cleaned, and then soldered. The remainder of the winding is put on and the ends secured. When placing the Empire cloth over this and the subsequent winding it will be necessary to cut a hole in the centre to permit withdrawal of the tapping.

The Final Winding

The last winding, of No. 16 D.W.S. is then put on—the ends are secured as previously described, and after thirteen turns have been put on, the wire is bent up, secured with tape and cut. Thirteen more turns are then

Table II

Showing Turns and Gauges of Wire for different Primary Voltages

Voltage Supply.	Primary Current (approx.)	Primary Turns.	Wire Covering and Gauge.	
50	0·85	300	22 D.S.C. or 21 enamel	
75	0·56	450	23 D.S.C.	
100	0·42	600	24 D.S.C.	
110	0·38	660	25 D.S.C.	
120	0·35	720	26 D.S.C.	
150	0·28	900	27 D.S.C.	S.W.G. copper wire.
200	0·215	1200	28 D.S.C.	
210	0·20	1260	—	
220	0·19	1320	—	
230	0·185	1380	—	
240	0·18	1440	—	
250	0·17	1500	29 D.S.C.	

Current density at 1,200 amperes per square inch.

put on, and the starting end is bent up with the finishing end of the first thirteen turns. These two constitute the centre tapping, and a piece of sleeving of 2 mm. or 3 mm. is slit at one end and is placed over both wires with the slit end towards the winding. The covering of Empire cloth will have to be cut as previously to permit of the tappings being taken through.

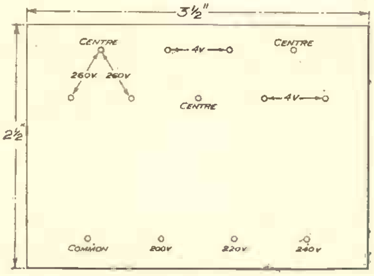


Fig. 9.—SUGGESTED LAYOUT OF TERMINAL BOARD.

Construct from Paxolin or Bakelite Sheet ⅛ inch or $\frac{3}{16}$ inch thick.

Taping the Whole Winding

The whole winding may then be taped, and, after testing, the tape may be given a coat or two of varnish to give a good finish to the job.

How to test Insulation

Should a Neon lamp be available, the insulation between windings may be tested as the work proceeds. This can be done by connecting the lamp in series with the mains, as shown in Fig. 7. Care should be taken not to touch the bare ends of the wires with the fingers, as this will pass a small current which will give a glow in the lamp similar to that produced by leakage between windings. Should the insulation be good no glow should be noticeable when the lamp is connected between adjacent windings.

Testing Windings

The windings themselves should be tested for continuity either with the Neon lamp or with a battery and galvo.

Constructing the Core

The core is the next item, and examination of the stampings will reveal that they are in the form of T's and ⌊⌋'s. These should be placed in the core alternately, care being taken that the paper-covered sides face all one way. Squeezing these in the vice whilst assembling will facilitate the process. About 100 pairs of laminations are required to fill the core.

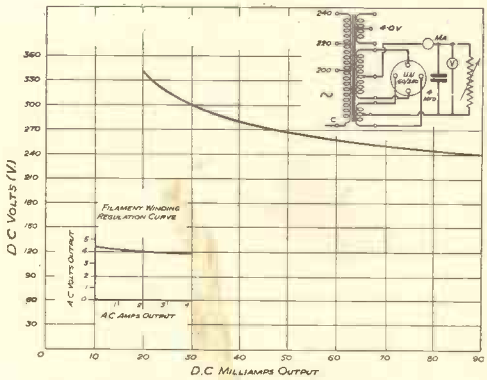


Fig. 10.—REGULATION CURVE OF TRANSFORMER.

With Mazda U.U. 60/250 rectifying valve.

Clamps

Suitable clamps can be made from ¼-inch iron strip, but it is more advisable to use the commercial type of cast clamps, which can be purchased quite reasonably and afford a better method of securing the laminations.

The Secret of Insulating Joints

A few remarks regarding the making of joints and winding will not come amiss.

Prior to making a joint, a piece of sleeving should be slipped over the wire. The two ends are then cleaned, twisted together and soldered, care being taken to make a smooth soldered joint. After this the sleeving is slipped over the joint and provides adequate insulation (see Fig. 8). The sleeving should be cut long enough to cover ¼ inch past the end of the insulation on the wire. Rosin-cored solder is the most satisfactory for use on joints. Killed spirits and other corrosive fluids or fluxes should on no account be used.

Hints about Winding

The wire should not be wound on loosely neither should it be kept so taut as to cause stretching. The dimensions given allow for the winding being piled, and slots are shown on the bobbin so as to allow for different thicknesses of covering and different ways of winding (see Fig. 4).

When winding do not hold the wire with the bare hand, but rather with a dry piece of felt or chamois leather. This will prevent any perspiration from the hands reaching the winding and so providing a fruitful source of eventual breakdown. Mark every 100 turns on a strip of paper when winding. This will often avoid confusion as to the turns wound on.

Terminal Board

Details are given in Fig. 9 of a suitable terminal board and lay-out of terminals, and it is left to the reader's discretion whether he uses this arrangement or prefers to use an arrangement of his own.

NOTES ON USING THE TRANSFORMER

It will be noticed that the output from the transformer is rated at 260 volts. This has been arranged so that if a smoothing choke having a resistance of approximately 167 ohms is used, the smoothed output at 60 milliamps will be of the order of 250 volts, which is quite adequate for the majority of receivers.

The low-voltage rectifier winding will supply 2 amperes at a voltage of 4 volts, which is quite adequate for all rectifying valves suitable for use with the transformer.

Lowering the Secondary Output

Should it be desired to lower the secondary output to suit certain rectifying valves which will definitely not stand more than 250 + 250 volts, this can be done by winding each half-secondary with 1,500 instead of 1,560 turns. The voltage may be reduced to any desired value. Multiplying the voltage required by 6, which is the turns per volt, will give the required turns.

The valve used in the tests was the Mazda U.U. 60/250 rectifying valve, and the makers state definitely that this valve will work satisfactorily with up to 300 volts per anode. The majority of rectifying valves will definitely stand the 260-volt output.

THE USE OF THE REGULATION CURVE

The curve shown is one of the transformer with valve and not of the transformer alone. This curve is the most useful one, as it shows what voltage we may reasonably expect to receive if we take a certain number of milliamps and conversely, that is provided we use the same kind of rectifying valve as that with which the curve was taken—in this case a Mazda U.U. 60/250 Rectifying Valve was used.

For example, a certain receiver will require 40 milliamps at 200 volts. From an inspection of the curve it will be seen that 280 volts (approx.) are delivered at this output. We will assume that a smoothing choke having a resistance of 250 ohms is used. Then, by Ohm's law, the voltage lost in the choke will be $250 \times 0{\cdot}04$, which is 10 volts. This brings the voltage to $280 - 10 = 270$ volts. We have to drop this 70 volts and can do so by means of a resistance whose value can again be calculated by Ohm's law.

We have to drop 70 volts. Now the resistance required to do this will be equal to 70 divided by 0·04 ohms, which is 1,750 ohms. This could be added in series with the choke before the last smoothing condenser or after the choke with an additional smoothing condenser. The smaller curve shows the low-voltage alternating-current output.

Table of Various Windings

In conclusion the reader's attention is drawn to the table showing the various windings to suit various primary voltages (Table II.) These windings will all occupy approximately the same space as the one described in this article, and the length of wire required can be calculated from the fact that the average length of a primary turn is 8½ inches.

The writer would like to take this opportunity of thanking Messrs. Sound Sales Ltd., of Tremlett Grove, Junction Road, Highgate, N.19, who provided the bobbin and clamps used in the present construction, and from whom the stampings, wire and other material may be obtained.

A SCREEN-GRID PENTODE TWO

By HERBERT H. DOWSETT

THE set described in the following article has been designed to satisfy the really critical listener, its outstanding features being: (1) Ample volume with a reasonable current consumption; (2) Adjustable selectivity, giving complete freedom from interference; (3) Tone correction of the pentode output valve, giving clear and mellow results with even the cheapest forms of loud speaker.

A glance at the accompanying illustrations and circuit will show that the set is quite a simple one to construct, and anyone should be able to build it entirely in one evening.

The Circuit

This two-valve arrangement gives exceptionally good results on both the long and medium waves. The ·0003 variable condenser, with shorting position, in series with the aerial, gives a fine degree of selectivity on the medium waves, and in the shorted position, directly couples the aerial to the coil, when the set is to be used on the long wave-band. The ·0003 mfd. fixed condenser across terminals 4 and 7 of the coil serves to remove interference from the more powerful short-wave stations when the set is switched over to long waves. Intervalve coupling is by means of a 3-1 ratio L.F. transformer, and automatic grid-bias eliminates the necessity of a separate battery.

The pentode output valve ensures ample loud speaker volume and the double tone correction cuts out any tendency to shrillness, a fault so frequently found when this type of valve is used.

Constructional Hints

Drill the front panel from the dimensions given in Fig. 1. The actual dimensions of the holes are not given, as in many cases it was unnecessary to specify a particular make of component, and the diameters of bushes of different makes vary considerably. For this reason, too, no definite layout of the components on the baseboard is given, it being more convenient to place the components in the approximate positions shown in the wiring diagram, so that they can be moved about if necessary.

Fit the switches and condensers in their respective positions, then screw the pane to the baseboard by means of the three holes in the lower edge, as shown in the diagram.

List of Components

1 Panel, 10 inches by 6 inches.
1 Terminal Strip, 10 inches by 1½ inches.
1 Baseboard, 10 inches by 8 inches.
1 ·0005 mfd. Tuning Condenser, with slow motion drive.
1 Dual Range H.F. Coil. *Colvern.*
1 ·0003 mfd. Solid Dielectric Condenser with shorting position. *Ready-Radio.*
1 ·0003 mfd. Differential Reaction Condenser.
1 Three-point Switch. *Polar.*
1 Two-point Switch.
1 L.F. Transformer. Ratio 3-1.
1 Five-pin Valve Holder.
1 Four-pin Valve Holder.
1 Fuse and Holder.
1 7500 hm Spaghetti Resistance. *Lewcos.*
1 10,000 ohm Spaghetti Resistance. *Lewcos.*
1 ·0003 mfd. Fixed Condenser. *Dubilier.*
1 ·0002 mfd. Fixed Condenser. *Dubilier.*
1 ·002 mfd. Fixed Condenser. *Dubilier.*
1 ·01 mfd. Fixed Condenser. *Dubilier.*
1 1 mfd. Non-inductive type Condenser.
1 1 megohm Resistance.
1 ·1 megohm Resistance.
1 75,000 ohm Resistance.
10 Terminals.
1 Valve Screen. *Six-Sixty.*
Wire, Flex, Screws, Plugs, etc.
2-volt Accumulator, 120- to 150-volt H.T. Battery. Cossor Metallised Screen Grid Valve. Type 220 SG. Mazda Pentode Valve, Type Pen. 220.
Cabinet.

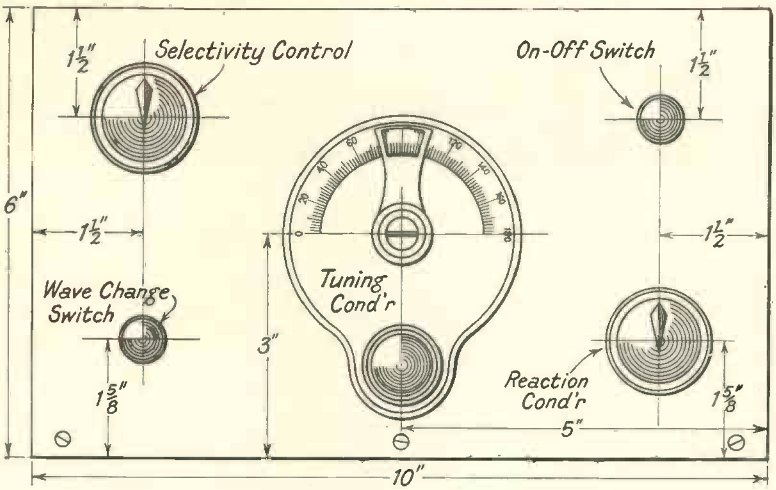


Fig. 1.—Showing the Layout of the Front Panel.

panel, immediately under the tuning condenser. When this is screwed into position, set out the remainder of the components, with the exception of the resistances, in the pcsitions indicated on the wiring diagram. Carefully space them to give easy access to all connections for wiring. The two fixed condensers shown on top of the coil are held in position by their connecting wires, and it is unnecessary to fix them in any other way providing they rest on top of the coil and are not suspended in the air.

The Terminal Strip

Drill the terminal strip to accommodate the ten terminals, and also three holes along the lower edge, similar to those in the front panel, by means of which the strip will be screwed to the back of the baseboard. The first terminal should be ½ inch from one end, and the remainder at 1 inch intervals throughout the length of the strip. If the terminals to be used are fairly large, it is a good plan to stagger them, putting the first, third, fifth, seventh and ninth on a line ¼ inch from the upper edge of the strip, and the second, fourth, sixth, eighth and tenth on a line ¾ inch from the upper edge. This will allow more room for wiring. Having mounted the terminals, fix the strip along the back edge of the baseboard.

Mounting the Components

The first component to be fixed is the 1 mfd. fixed condenser, which lies flat down on the baseboard, close up to the front

Wiring

The wiring can be carried out with any of the covered connecting wires sold for that purpose, or with bare tinned copper wire in conjunction with a suitable sized insulating sleeving. The former method

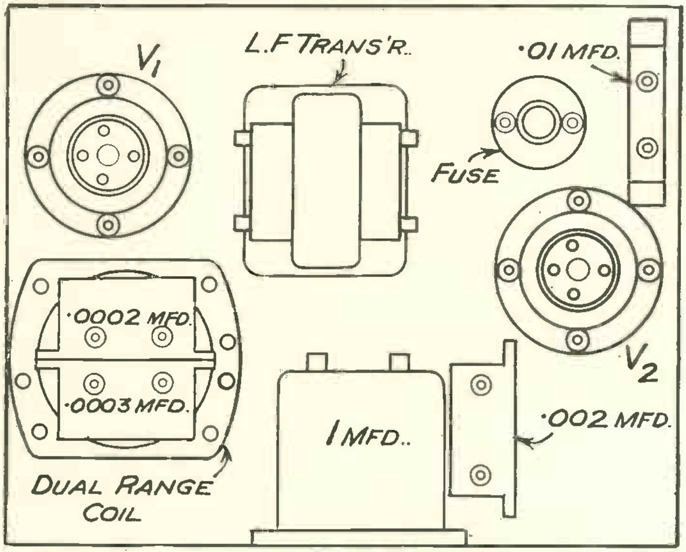


Fig. 2.—Layout of Components on the Baseboard.

usually results in a neater finish, and is therefore recommended.

What to Do if a Screen-Grid Valve is Not Used

It will be noticed that no terminal is used for the H.T. + 1 connection, but that a flexible lead is brought direct from the valve holder to the H.T. battery. This arrangement is to permit the use of an ordinary three-electrode detector valve (which gives quite good results), in place of the screen-grid. To effect this alteration, it is only necessary to remove the H.T. + 1 lead altogether, and connect the flexible lead which normally goes to the anode of the screen-grid, to the anode terminal of the valve holder.

Coil and Condenser Leads

All coil and condenser leads should be reasonably well spaced when running parallel, but the general arrangement of the remainder of the wiring is unimportant.

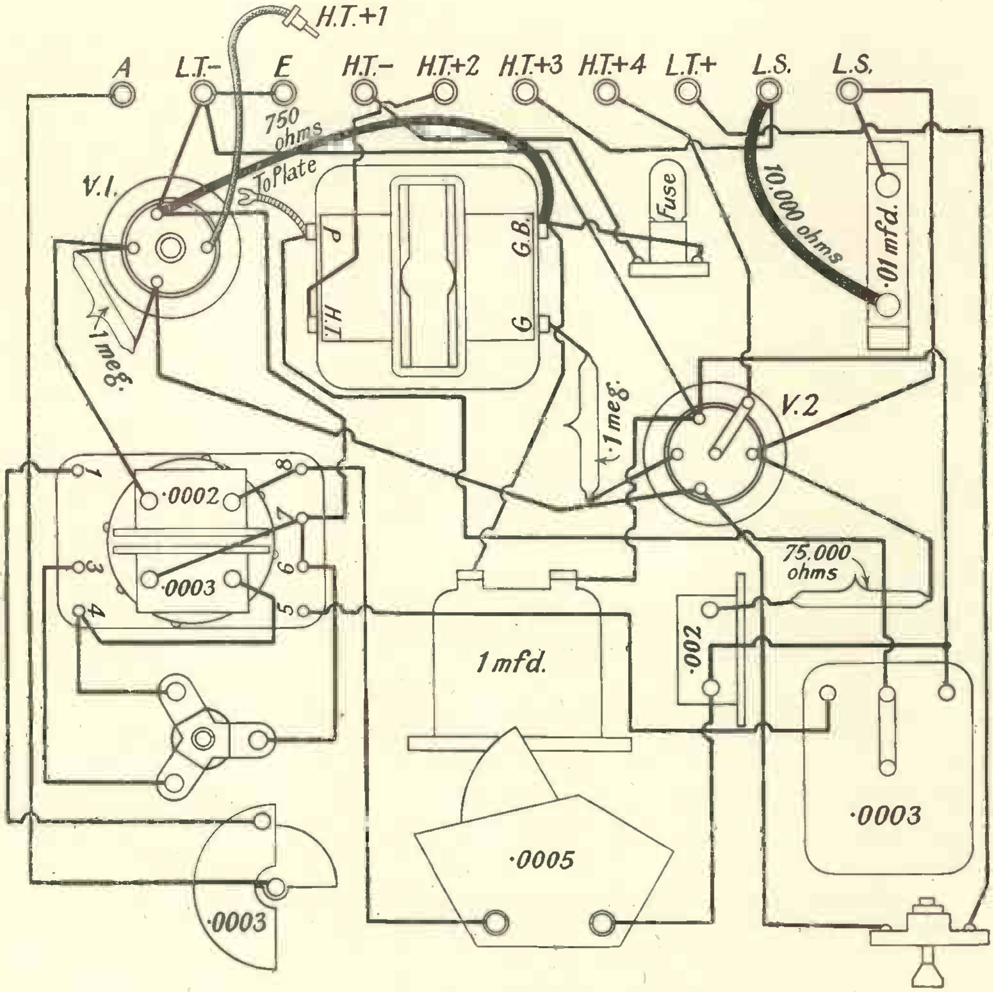


Fig. 3.—COMPLETE WIRING DIAGRAM.

Fitting the Screen

Directions for correctly fitting the screen to the screen-grid valve are supplied by the makers, and the following point should be specially noted: The metallised surface of the valve is earthed to one of the filament legs (usually marked E), and this leg is the one which must pass through the tag on the screen before the set screw is tightened on to the valve cap.

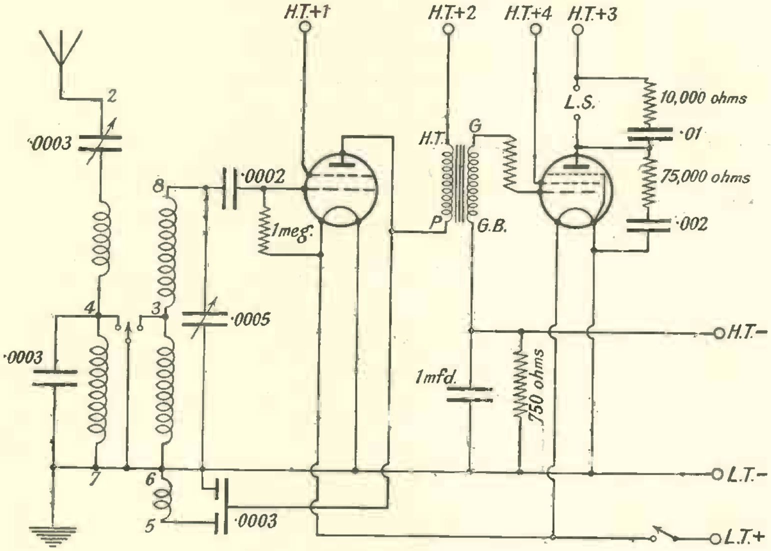


Fig. 4.—CIRCUIT DIAGRAM.

The first figures in each case relate to a 120-volt battery, and the second figures to a 150-volt battery.

Screw in the fuse and insert the valves. Test the set on the medium waves (wave change switch pulled out). Tune in the "local" station, and then adjust the selectivity control until reasonably fine tuning is obtained. When tuning on the long waveband this control should be turned to the extreme right in order to short the condenser, but this position on the medium waves will give broad tuning.

An ordinary power output valve may be used instead of the pentode without alteration of the wiring, but performance and volume will suffer a good deal.

Operating the Set

The H.T. + leads should be taken to the following tappings :—

H.T. + 1 to 60–80 volts.
H.T. + 2 to 90–100 volts.
H.T. + 3 to 100–120 volts.
H.T. + 4 to 120–150 volts.

When Using a Mains Eliminator

If it is desired to use a mains eliminator which does not provide for four H.T. + tappings, the H.T. + leads 3 and 4 may be joined together into one plug, and must be taken to the maximum tapping up to 150 volts.

HOW CAN ACCUMULATOR ACID BE TESTED FOR IMPURITIES?

The purity of sulphuric acid suitable for use in accumulators is determined by—

(*a*) The concentrated acid should be colourless, with a specific gravity of 1·84.

(*b*) The absence of copper impurities. *Test*—neutralise a quantity (100 cubic centimetres) of the acid with ammonium hydrate and add a 10 per cent. solution of ammonium nitrate. If the acid contains copper impurities, a reddish brown tint will be given to the prepared solution when a drop of potassium ferro-cyanide is added.

(*c*) The absence of arsenic impurities. *Test*—place a small amount of zinc (arsenic free) in a flask provided with a two-holed stopper, fitted with a thistle funnel, and a right-angle glass tube, which is connected to a wide hand glass tube. Drop some of the acid through the funnel into the flask and close the tap. Arsene gas will be generated if the acid contains arsenic impurities. The gas is detected by heating the wide hand glass tube through which it passes, when a mirror of metallic arsenic will be produced inside the tube.

MODERNISING OLD-STYLE WIRELESS SETS

By E. W. HOBBS

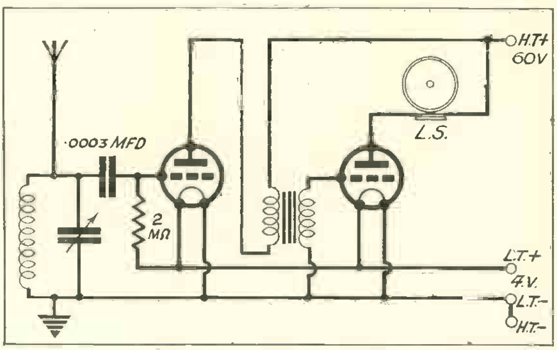


Fig. 1.—Two-Valve Receiver.
An elementary and much-used circuit.

Assuming that the set under consideration is in working order, the ideal method when the necessary instruments and facilities are to hand, is to construct a circuit diagram by tracing the actual wiring, putting on it the observable values of the components, and then testing to ascertain the remaining values.

Next, follow the usual principles of set designing and make such alterations to the circuit and to the values of components as may be deemed necessary to attain the desired results.

This done, it is a simple matter to alter the set accordingly, treating it in much the same way as if making a new receiver.

Unfortunately, it is not always possible to work in this scientific manner and in practice direct experiment is the only practical course to follow, owing to the presence of so many unknown values in the set.

A few general principles can be enunciated and may form the basis of practical work.

Increasing the Volume of Sound

To increase the volume of sound the set must be made to pass to the loud speaker a larger amount of current, either by voltage increase or by greater amperage, or by reducing losses in the set, or by increasing the sensitivity of the detector and the efficiency of the tuning coils, or by a combination of these and other contributory causes. The loud speaker itself must, of course, be capable of handling the maximum load, otherwise it must either have attention or be replaced. The use of a power valve or the addition of an extra stage of low-frequency amplification are obvious aids in the desired direction.

How these principles can best be applied in practice is described later on in this article.

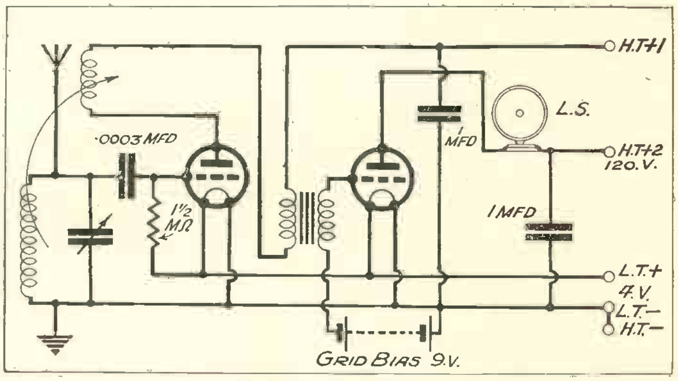


Fig. 2.—The Improved Two-Valve Circuit.
The circuit seen in Fig. 1 is here shown with additions that increase the volume of sound.

Increasing the Sensitivity

Increase of sensitivity implies an ability to receive a larger number of stations

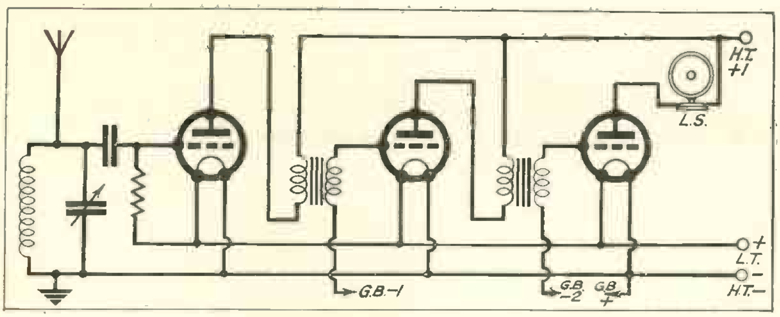


Fig. 3.—THREE-VALVE RECEIVER.
A simple circuit with two stages of transformer coupled L.F. amplification.

transmitting on wavelengths within the tuning limits of the set.

Improvements in sensitivity are often difficult to realise, but in general can be attained by concentrating on the detector valve and associated components, when the detector is the first valve. Other general causes of improvement are increased efficiency of the aerial tuning circuit, reduction of high-frequency losses in the aerial circuits, reduction of resistance in the earth circuit.

Contributory aids include the correct adjustment of detector anode voltage, correct adjustment of detector grid condenser, and particularly the value of the grid leak resistance. Very often a marked improvement is attained by the provision of a really efficient means of controlling the reaction. The addition of a stage of high-frequency amplification is an effective aid whenever it can be applied.

Improving the Selectivity

Problems of selectivity are in a class by themselves and are very difficult to deal with in general terms, although the application of one or more of the following hints will usually prove to be beneficial.

At the outset it is desirable to discriminate between sets with a single tuning circuit and those with multiple tuned circuits. In the first case the best improvement is to use an aperiodic (untuned) coupled aerial coil, or to separate the aerial circuit into two distinct portions, the first consisting of the aerial input with a coil having one or two turns loose coupled to a secondary circuit consisting of the original tuning coil and condenser.

Variations of this principle include the addition of a tuning condenser in the primary aerial circuit ; the provision of means for varying the degree of coupling between the primary and secondary coils either independently of, or in conjunction with, the tuning condenser. A much recommended device to increase selectivity is to provide a low value fixed condenser in series with the aerial circuit.

Another effective plan is the provision of a complete tuning unit arranged in series with the aerial input and the set.

What to Do with Multi-tuned Circuits

In the case of multi-tuned circuits the foregoing suggestions can be adopted so far as they apply, but generally an improvement must be sought by a comprehensive revision of the entire circuit and its components from the aerial input to the grid of the detector.

The substitu-

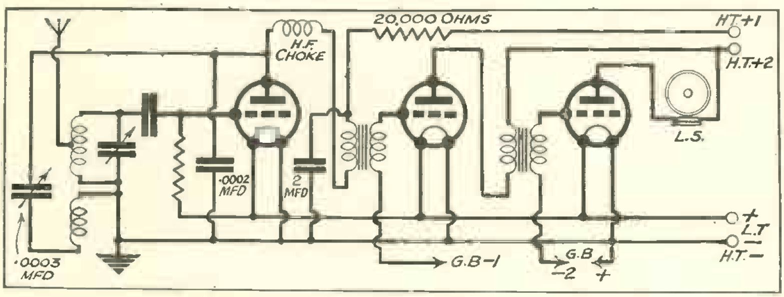


Fig. 4.—THREE-VALVE CIRCUIT MODIFIED FOR INCREASED SENSITIVITY.
The circuit shown in Fig. 3 is improved by adding re-action, and an aperiodic coupling in the aerial circuit and a separate H.T. lead to the detector valve.

tion of modern high efficiency coils for those of earlier pattern, will be found very beneficial, and is probably the most satisfactory and practical proceeding, particularly when the original coils were wound on cardboard formers and heavily coated with shellac.

Tonal Qualities

Appreciation of the musical qualities of a receiver and its associated loud speaker depend greatly upon the musical sensibility of the individual, consequently it is sometimes difficult to attain the desired end in a satisfactory manner, because one listener prefers a "shrill" or high-pitched quality, whereas others may prefer an accentuated bass and imagine it to impart a greater measure of sonority.

The Loud Speaker

Assuming the set under consideration is functioning in a reasonable manner, attention can be focussed on the output stage of the receiver and the loud speaker itself. The latter can be tested, whenever possible, on another receiver known to have good tonal qualities. If satisfactory, any loss in quality must be looked for in the receiver. If an old-fashioned type of horn loud speaker is still being used, it should be replaced by a latest type cone speaker, preferably of the moving coil variety.

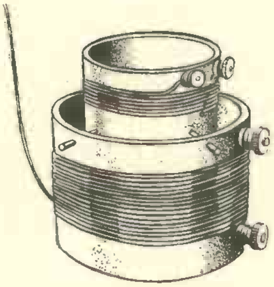


Fig. 5.—ARRANGEMENT OF REACTION COIL.

The coil is wound around an ebonite former inserted partly into the tuning coil.

Methods of Improving the Quality

Methods of improving the quality include the judicious introduction of by-passing condensers, the provision of adequate power—say as a minimum of 150 to 200 milliwatts—from the last valve.

Using Modern Transformers

The substitution of modern transformers for those of earlier pattern or the introduction of an output transformer in the anode circuit of the last valve. The latter course enables the impedance of the loud speaker to be matched up with that of the output valve.

Fixed condensers shunted across the loud speaker terminals often have the effect of lowering the pitch. Correct grid bias voltage is most important.

Tone control units, as well as an efficient volume control unit, are frequently found of practical value.

The first essential, however, is to locate the seat of the main trouble, and this can best be done by the use of a milliampere meter, as will be explained later.

Specific Examples

The following examples of alterations to receiving sets will serve in some measure to point out some practical ways in which the older types of battery operated sets can be improved in performance.

INCREASING VOLUME FROM TWO-VALVE SET

The circuit diagram, Fig. 1, shows a plain 2-valve set consisting of detector and transformer coupled L.F. amplifier; it was required to increase the volume of sound to the maximum; reception from local station only being desired.

Examination of the components showed that the chief loss of volume was due to poorly chosen valves and a lack of H.T. voltage to the anode of the L.F. valve.

The First Alterations

First a few turns of No. 22 gauge enamelled wire were wound around the aerial coil and connected into the anode circuit of the detector valve to act as a reaction coil—as indicated in the circuit diagram, Fig. 2, which shows the same set as modified.

Inserting a Separate High-tension Lead

A separate high-tension lead was wired up and consisted of a flexible between the H.T. terminal of the L.F. transformer and a wander plug for the H.T. battery tap. The anode terminal of the L.F. transformer was wired to one end of the reaction coil; a connection from the other end of the reaction coil was taken to the anode of the detector.

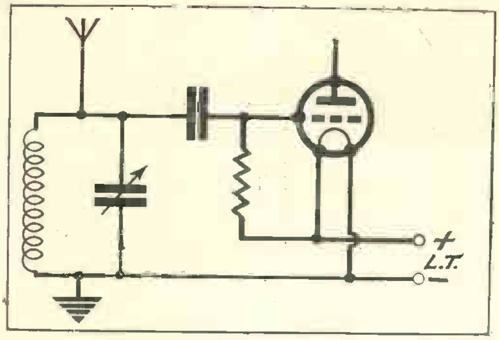


Fig. 6.—Early Tuning Circuit.
This simple circuit tunes very broadly.

Reducing the Value of the Grid Leak

The grid leak was reduced in value from 2 megohms to 1½ megohms, and a grid bias battery connected in the usual way to the secondary of the L.F. transformer. A small power valve with 120 volts H.T. on the anode was used in the last valve-holder, and this, in conjunction with a good detector valve, almost doubled the audible sound from the loud speaker, which under these conditions was then operating at maximum load. The tone was somewhat improved by correct biassing of the L.F. valve.

GETTING MORE STATIONS

The next example is a 3-valve set, a conventional detector and 2 L.F. circuit as given in Fig. 3, which it was desired to convert to an "ether searcher" for use with loud speaker or headphones.

Examination showed that the last two stages were adequate and no alterations were needed, all the work being concentrated on the detector stage and the aerial tuning.

Alterations in the Tuning System

The alterations can readily be appreciated by comparing Fig. 4, showing the circuit as modified, and Fig. 3, showing the old circuit. The main alterations were that the aerial input was taken to a tapping on the third turn from the bottom of the aerial coil, a reaction coil was specially wound on a circular former and arranged to slide inside the tuning coil — as shown in Fig. 5—the reaction coil being held in place by three wooden pegs. The degree of coupling was determined by experiment, the pegs being fixed finally by means of glue.

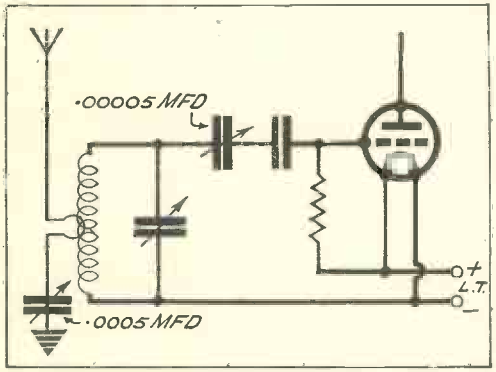


Fig. 7.—Improved Tuning Circuit.
The aerial is coupled to the tuning coil by a single turn and tuned by a series condenser.

Adding a High-frequency Choke

A high-frequency choke was added to the detector anode circuit together with a 20,000 ohm resistance in series, a 2 microfarad decoupling condenser, and a by-pass condenser.

Arranged in this way, the set under consideration was greatly improved in sensitivity, selectivity was sufficient for the purpose, while the signal strength was sufficient to enable a loud speaker to be used on many distant stations. Subsequently a ·0005 mfd. tuning condenser was used in the aerial circuit partly to increase selectivity, but chiefly as a crude form of volume control.

INCREASING THE SELECTIVITY

Several methods of improving the selectivity of early sets have already been mentioned, and some are illustrated here in circuit form.

The first, shown in Fig. 6, had a plain coil wound on a cylindrical former, and was a very broad tuner, quite inadequate for modern conditions.

Adding a Neutrodyne Condenser

The alterations consisted of making a single turn of No. 16 gauge bell wire around the coil windings and connecting one end to the aerial input terminal, the other end was connected to a ·0005 mfd. tuning condenser in series with the earth lead, as shown in Fig. 7, and a neutrodyne type of variable condenser with a value of about ·00005 mfd. added to the grid lead of the secondary circuit. Extremely sharp tuning is possible by careful independent adjustment of the two tuning condensers. Normally the neutrodyne condenser is used at maximum, and only altered to give a final sharpness to the tuning. Often it is the means of cutting out unwanted background noises.

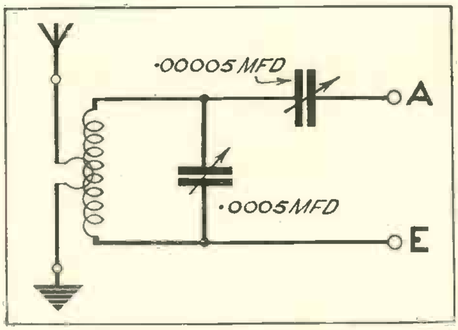


Fig. 8.—A TUNING UNIT.

This unit is used in series between the aerial and the receiving set; it largely eliminates interference and sharpens the tuning.

Constructing a complete "pre-Receiver" Tuning Unit

Another effective plan is to construct a complete "pre-receiver" tuning unit as shown in Fig. 8, consisting of a single turn in the aerial circuit, closely coupled to the secondary coil. The secondary coil is tuned by a ·0005 mfd. variable condenser and a neutrodyne condenser in series in the output lead to the terminal A. To use the unit, connect the output terminals to the aerial and earth terminals on the set. Connect the unit to aerial and earth as usual. To tune, set the neutrodyne condenser to maximum capacity, then turn slowly the tuning condensers on the unit and on the set until a station is heard. Adjust each condenser separately until maximum results are attained, noting the dial readings for future reference. It should be appreciated that dual range coils can be used in any of the previously mentioned circuits provided the wave change switch is added as usual.

IMPROVING TONE

Much time and annoyance can be saved by the use of a milliammeter. With this meter the fluctuations of anode current flowing through the last valve can be observed.

Connect the meter in series in the anode circuit of the last valve only, then when the set is switched on, but not receiving signals, the meter reading should indicate a steady current within a few milliamps. of the figures indicated in the valve makers' pamphlets.

If there is any marked discrepancy, check the voltages.

How Distortion is Indicated

When the valve is in order, the current flowing, and the meter reading is steady, tune in a powerful station and gradually increase the volume. Watch the meter and note how it vibrates, at first only slightly and more or less steadily, but with increased volume it generally kicks or vibrates in jerks, thus indicating that the set is overloaded and distortion is taking place.

A Test for the Loud Speaker

This indicates that the trouble is in the set, but if distortion and loss of musical quality—or the worse trouble commonly called "blasting" is heard from the loud speaker while the meter reading remains fairly steady, the loud speaker is at fault.

Testing for correct Grid Bias

Still another indication of the causes of trouble can be obtained from the meter readings. Tune in a station and adjust the volume so that the meter needle kicks are not too pronounced, then carefully increase the volume, and if the kicks then predominate on the upwards, or increased current side, it indicates that H.T. voltage is too low or the grid bias voltage is too high. If the kicks are mainly in the reverse direction, the grid bias voltage is probably too low.

SIMPLIFIED TESTING OF WIRELESS COMPONENTS

By H. E. J. BUTLER

Fig. 1.—THIS SHOWS THE SIMPLE APPARATUS REQUIRED FOR THE TESTS DESCRIBED IN THE FOLLOWING ARTICLE.
The moving coil meter is essential only for testing high resistance components.

THE tests described here do not involve the use of expensive apparatus or the accurate determination of values. Where possible a method of finding approximate values is given when it can be accomplished by simple methods. These tests are made before constructing a set to find out whether the components have any radical faults likely to result in absolute failure of the assembled set or to cause damage to other parts of the receiver. Most of the tests are made with the aid of a cheap moving iron voltmeter and battery. A high resistance moving coil voltmeter is, however, necessary for checking high resistances and grid leaks.

Fixed Resistances

The continuity of fixed resistances may be tested with a pocket voltmeter of the moving iron type. The range of the meter and the voltage of the testing battery decide the limit of the resistance which it is possible to test. The moving iron type of voltmeter is not very sensitive, the worst types generally take some 150 milliamperes for full-scale deflection, so that this kind of meter is suitable only for testing low resistances and resistances which are rated to carry 25 milliamperes and

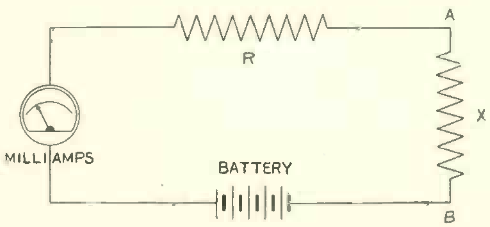


Fig. 2.—THE CIRCUIT USED FOR TESTING RESISTANCES.

X is the resistance under test, and R is a protecting resistance. When a voltmeter is used instead of a milliammeter, the resistance R is part of the instrument.

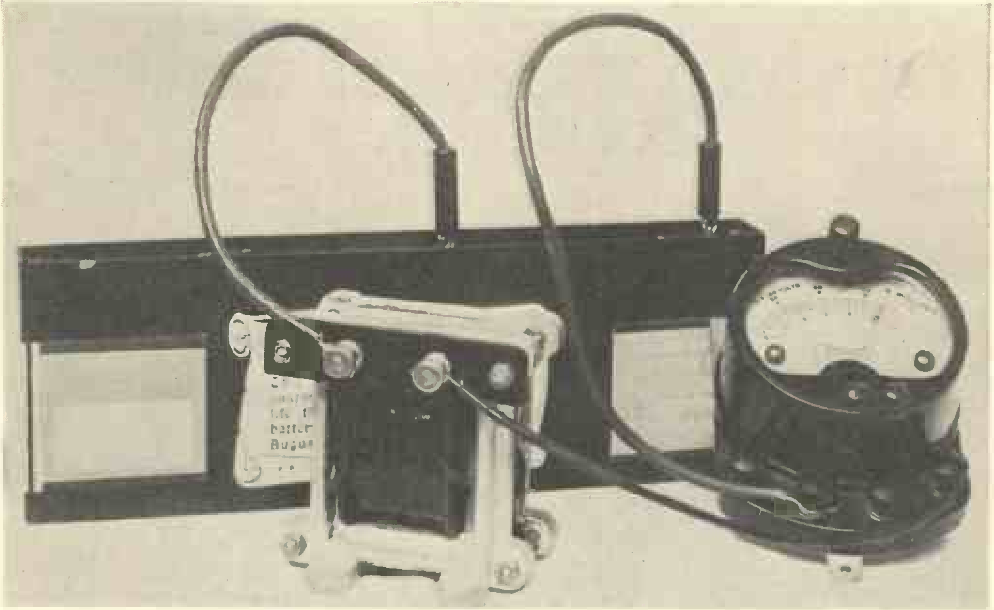


Fig. 3.—TESTING A SMOOTHING CHOKE FOR CONTINUITY AND RESISTANCE BY MEANS OF A VOLTMETER AND GRID BIAS BATTERY.

over. The resistances in this class are self-bias resistances and D.C. mains resistances.

When to Use a Moving Coil Voltmeter

High resistances, which are used for decoupling and as voltage dropping resistances in anode circuits may be tested with a moving coil voltmeter of 200 ohms or 1,000 ohms per volt. The 200 ohms per volt class of voltmeter gives a full-scale deflection at 5 milliamperes, while the more sensitive type of 1,000 ohms per volt gives a full-scale deflection at 1 milliampere.

A voltmeter is used for testing continuity and resistance because it is more convenient and safer than using a milliammeter. If a milliammeter is used it is necessary to insert a resistance in circuit to limit the current in the event of a short circuit across the component being tested. A milliammeter has the advantage that direct calculation of the value of the resistance is possible from the reading.

How to Make the Test with a Voltmeter

Fig. 2 shows the circuit for testing resistances with a voltmeter or milliammeter. X is the resistance on test and R is the series resistance of the voltmeter or the protecting resistance of the milliammeter. Suppose a 7·5 volt moving coil voltmeter of 200 ohms per volt is being used, with a 7·5 volt battery tapping. With A and B short circuited, the meter gives a deflection of 7 volts. This is the real voltage of the battery. With resistance X in circuit the voltmeter now reads ·5 volt. This is equivalent to a current reading of $\frac{1}{3}$ milliampere, since a reading of 7·5 volts is equivalent to 5 milliamperes; ·5 volts is equivalent to $\frac{5}{7 \cdot 5} \times \cdot 5$ milliampere. The total resistance of the circuit, from Ohm's formula :—

$$R = \frac{E \times 1{,}000}{I},$$

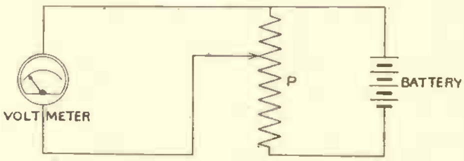


Fig. 4.—THE CIRCUIT USED FOR TESTING A POTENTIOMETER.

The object of this test is not only to verify the continuity of the potentiometer, but to test the arm for bad contact at any point.

where I is expressed in milliamperes.

$$R + X = \frac{7 \times 1{,}000}{\frac{1}{3}}$$

$$R + X = 21{,}000 \text{ ohms.}$$

The resistance of X is, therefore, the total resistance of 21,000 ohms minus the meter resistance, which is 1,500 ohms. X therefore equals 19,500 ohms.

Testing with a Milliammeter

Consider an example using a milliammeter of full-scale deflection of 1 milliampere. This is to be used for checking a high resistance, so that a 100-volt battery is used. To limit the deflection of the instrument to 1 milliampere, in the event of a short circuit across A and B, a resistance of ·1 megohm (100,000 ohms) is used in series for R (see Fig. 2). The value of the protecting resistance is found from the formula $R = \frac{1{,}000\ E}{I}$, where E is the battery volts and I the full-scale current of the meter in milliamperes. The resistance X to be tested is now connected to A and B, which gives a current reading of ·05 milliamperes. The total resistance of the circuit is therefore :—

$$X + R = \frac{1{,}000 \times 100}{\cdot 05}$$

$$= 2 \text{ megohms } (2{,}000{,}000 \text{ ohms}).$$

$$X = 2 - \cdot 1 \text{ megohms.}$$

$$= 1\cdot 9 \text{ megohms.}$$

The accuracy of this result depends on the exact values of the protecting resistance and the voltage of the testing battery. The meter resistance is negligible.

The accurate measurement of resistances is dealt with in a separate article on the use of the Wheatstone Bridge.

Testing the Resistance of a Choke

Fig. 3 shows a test being made on a smoothing choke. The voltmeter scale is being used with a 7·5 volt tapping on the dry battery, which gives a full-scale deflection with the choke short-circuited. With the choke in circuit the meter reads 5 volts, which is equivalent to a current of 3·3 milliamperes, because the instrument resistance is 1,500 ohms. The total resistance of the meter and the choke is therefore :—

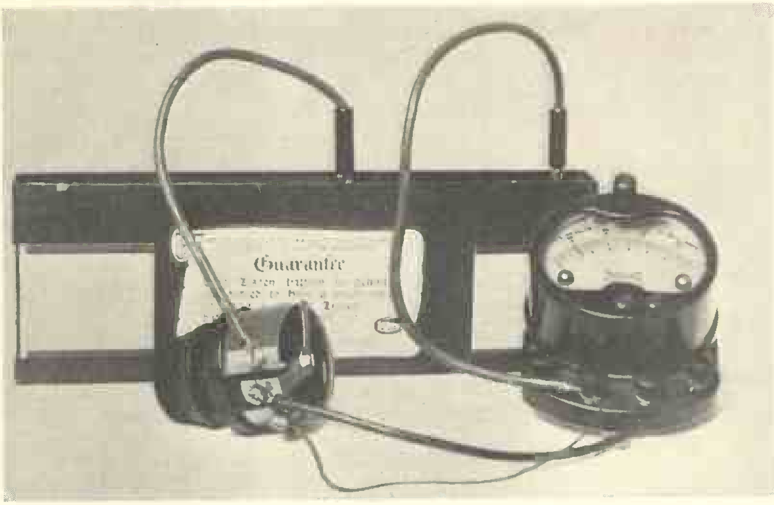


Fig. 5.—A Practical Illustration of the Circuit Shown in Fig. 4.

$$X + R = \frac{7\cdot 5 \times 1{,}000}{3\cdot 3}$$

$$= 2{,}280 \text{ ohms.}$$

The resistance of the choke is therefore 2,280 — 1,500 = 780 ohms.

Variable Resistances and Potentiometers

The total resistance of a variable resistance or potentiometer is tested in the same way as for a fixed resistance just described.

The chief test of a potentiometer is for smoothness of action and perfect contact of the moving arm in all positions. Fig. 4 shows a circuit for doing this, and Fig. 5 shows the apparatus in use. It is necessary to limit the voltage of the battery to the maximum which may be applied to the potentiometer.

Making the Test

The test is made by rotating the arm slowly over the resistance track. If the voltmeter needle flickers at any point it indicates a bad contact. This test can be used to indicate the maximum and minimum values of the potentiometer. The voltmeter used must be a 1,000 ohms per volt type for testing high-resistance potentiometers, while a moving iron voltmeter can be utilised for potentiometers of low resistance, which are used for bridging the filaments of indirectly heated valves and the heater windings of mains transformers, to obtain the electrical centre.

When testing resistances by any method which necessitates passing an appreciable current through them, care must be taken not to exceed the specified current rating of the resistance. The maximum voltage that may be applied across a potentiometer is given by $E = \sqrt{W \times R}$, where W is the watts rating of the resistance R ohms.

Chokes

Smoothing and output chokes are tested for continuity. The D.C. resistance of chokes seldom exceeds 1,000 ohms, so that this continuity test can be made with a less sensitive type of moving iron voltmeter. Low resistance continuity testing is satisfactorily accomplished by using one of the inexpensive pocket voltmeters with a self-contained 3-volt battery. It is not possible to measure the inductance of a choke with simple measuring instruments.

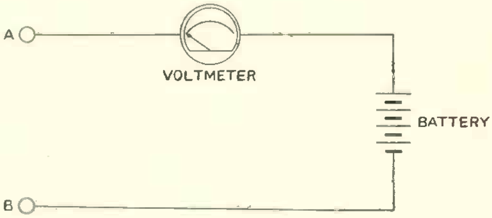


Fig. 6.—The Circuit of a Simple Continuity Test Set.

The component to be tested is connected across A and B. The battery voltage is adjusted to give a full-scale deflection with A and B short-circuited.

A Simple Continuity Tester

A circuit for continuity testing is shown in Fig. 6. The battery voltage should be adjusted to give a full-scale deflection, so that the test may be as sensitive as possible. For low-resistance circuits, such as switches and tuning coils, a lamp of the same voltage as the battery may be substituted for the voltmeter, as shown in Fig. 7.

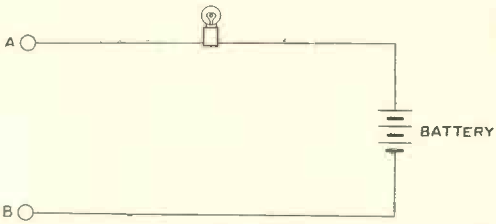


Fig. 7.—A Continuity Tester Using a Bulb in Place of the Voltmeter in Fig. 6.

This circuit is suitable for testing low-resistance circuits such as tuning coils and switches.

Tuning Coils

The matching of tuning coils and the measurement of their inductance will form the subject of separate sections. It is assumed here that the inductance is correct. The coils are tested for continuity with either of the tests shown in Figs. 6 and 7. It is advisable to test the coils not only across the entire winding but also across one end and each of the terminals connected to the tapping points. If a low-resistance voltmeter is used in the test (shown in Fig. 6) the self-contained switches of the coils may also be tried for indifferent contact. The extremities of

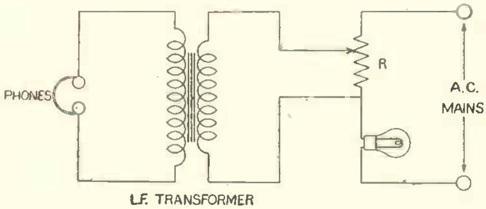


Fig. 8.—The Circuit for Testing a Low-Frequency Transformer without Measuring Instruments.

The bulb is a 25-watt size, and the potentiometer 30 ohms.

the coil are connected to the test points A and B (Fig. 6), and the switch then operated. With the long wave winding short-circuited, the reading on the voltmeter should rise due to the lower circuit resistance, and remain steady if the switch is good. A high-resistance voltmeter is unsuitable for this test because the resistance of a tuning coil is too low in comparison and the shorting of the long wave winding would not therefore give any appreciable difference in the voltmeter readings.

Intervalve Low-frequency Transformers

Unless a high-resistance voltmeter or low-reading milliammeter is available it indicated by a mains hum in the phones which are connected to the secondary terminals of the transformer. The low potential A.C. may be derived from the filament winding of any available mains transformer. If a suitable transformer is not at hand another method of obtaining the low voltage A.C. can be used. This is shown in Fig. 8. A 25-watt lamp is connected in series with a resistance of 20 to 30 ohms, such as might be provided by an obsolete filament rheostat or potentiometer suitably adjusted. The low volts A.C. is then tapped off the potentiometer.

Fixed Condensers

It is not possible to test, with any degree

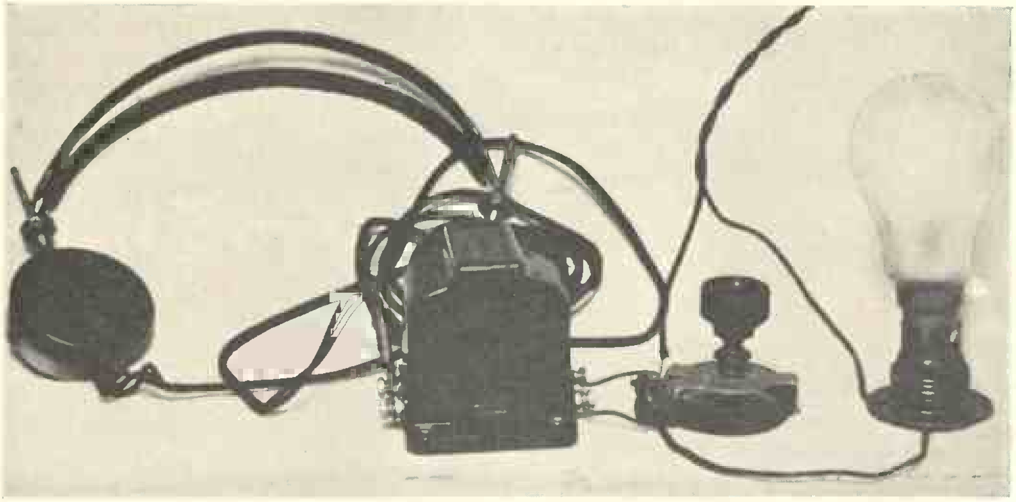


Fig. 9.—Testing a Low-frequency Transformer with the Circuit shown in Fig. 8.

is not possible to test the continuity of intervalve transformer windings with the testing circuit shown in Fig. 6 because the secondary winding is of very high resistance and will not safely pass any appreciable D.C. such as would be required to give a readable indication on a moving iron instrument.

A Useful Circuit

A circuit for readily proving the soundness of low frequency transformers is shown in Figs. 8 and 9. An A.C. voltage of 2–4 volts is connected to the primary winding of the transformer, and a continuous circuit in both windings is

of certainty, condensers which have a capacity of less than ·5 microfarad. The testing of small condensers, apart from a simple insulation test, is possible only with more expensive and elaborate apparatus. The tests on condensers of ·5 microfarad and over, which are given here, are to prove the insulation and ability to hold a charge.

The test consists of charging the condenser with a voltage not appreciably lower than the rated working voltage of the condenser, leaving it for about five minutes, and then discharging to discover whether the charge has been satisfactorily retained.

Voltage Required for the Test

A high D.C. voltage is necessary for this test. This may be obtained from D.C. mains, a high tension dry battery, or the unsmoothed D.C. of the eliminator for which the condensers may be intended. The high tension D.C. is connected directly across the condenser terminals, and as a protecting device a bulb must be put in series to protect the supply should there be an internal short circuit in the condenser. The circuit is shown in Fig. 10. If there is an internal short-circuit in the condenser the lamp will light continuously. When the testing voltage has been applied for about half a minute the mains are switched off and the condenser allowed to stand for about five minutes. The condenser terminals are then short-circuited with a screwdriver or short wire. If the charge has been held a spark is obtained.

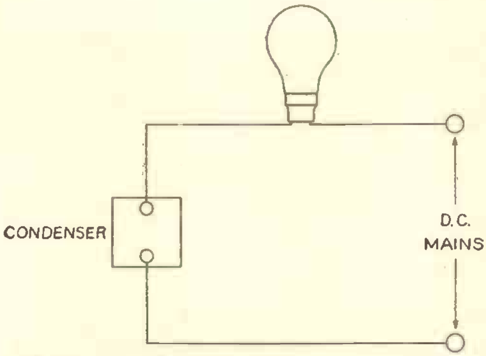


Fig. 10.—THE CIRCUIT ARRANGEMENT FOR CHARGING SMOOTHING CONDENSERS.

The lamp is inserted in the circuit as a protecting device.

What the Spark Indicates

The size of the spark will depend on the capacity of the condenser and on its insulation. If no spark is obtained on shorting the charged condenser, low insulation or internal disconnection is indicated. On no account handle the charged condenser, because the voltage across its terminals may be dangerous. Alternating current mains are not suitable for testing condensers in this way. Do not be tempted to apply a voltage equal to the manufacturer's test pressure. The test voltage, often stated on the condenser case, is applied for a few seconds only, and a further test at this voltage is not good for paper condensers, for while they may not be actually punctured, permanent injury can result which may lead to premature failure.

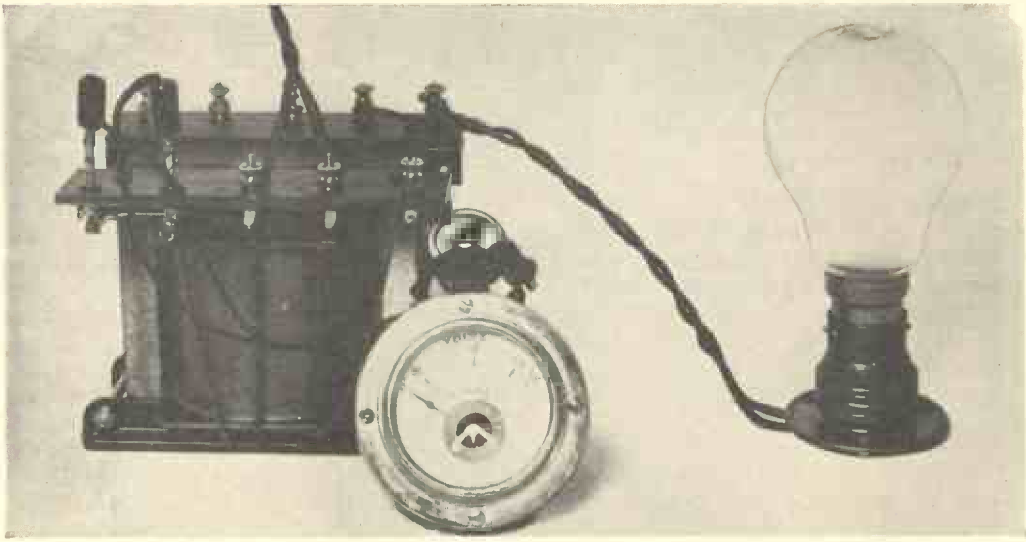


Fig. 11.—TESTING THE OUTPUT WINDINGS OF A MAINS TRANSFORMER.

The high voltage secondaries are tested with mains bulbs, and the 4-volt windings with a moving iron voltmeter or a small bulb.

Mains Transformers

The object of making a simple test on mains transformers is to prove the soundness of the various windings and to check the terminal connections of the different voltages.

The usual transformer for an all-mains set has one or more 4-volt windings and a high tension secondary of 135 volts upwards.

How to Test a Mains Transformer

To test a transformer first connect the primary to the correct mains voltage and leave the transformer without any load on the secondary windings for about fifteen minutes. If the transformer remains cold after this time it may be assumed that there are no short-circuited turns in any of the windings.

If the first test is satisfactory test the 4-volt windings with a miniature 3·5 or 4-volt bulb. A moving iron voltmeter may be used to test the 4-volt windings, as shown in Fig. 11. This class of instrument does not give an accurate indication of the secondary voltage, but gives a fair idea of the voltage on open circuit. The meter will probably indicate 4·25–4·5 volts.

Testing High Tension Secondary Windings

The high tension secondary windings are tested with a mains bulb of suitable voltage. Care must be taken to use a bulb which will not pass a current much in excess of the rated capacity of the winding under test. Usually a 25-watt 250 volt or 15-watt 100-volt bulb will be safe for all but the smallest sizes of transformers. This test is only momentary, not continuous, so that considerable latitude is possible in the voltage of the testing lamp. If the voltage of the secondary winding exceeds 250 volts on each side of the high tension secondary centre tapping, two bulbs are connected in series.

Centre-tap Test

Suppose a transformer has a secondary winding of 500 plus 500 volts for a valve rectifier, each half of this winding is separately tested with two 230–250 bulbs of the same wattage connected in series. It is possible that one-half of a centre-tapped winding may be connected the wrong way round, which results in zero voltage across the outer terminals. To check this, sufficient bulbs of the same wattage are connected in series across the outer terminals. Fig. 11 shows one-half of a centre tapped high tension secondary being tested with a 25-watt bulb.

Do not attempt to test with a lamp the secondary winding of a small grid bias rectifier transformer. These transformers are designed to pass only a very small potentiometer current of 5 milliamperes or so. In the absence of an A.C. voltmeter of high resistance the only way to test this type of winding is by a continuity test shown in Fig. 6.

A Useful Voltmeter

Voltmeters of the moving iron type are now available which read with the same degree of accuracy both on direct current and alternating current. They cost no more than a good class moving coil instrument. The wireless enthusiast is therefore advised to buy one of these double purpose instruments in preference to one of the moving coil type, which is suitable for direct current measurements only.

Testing Wired Components

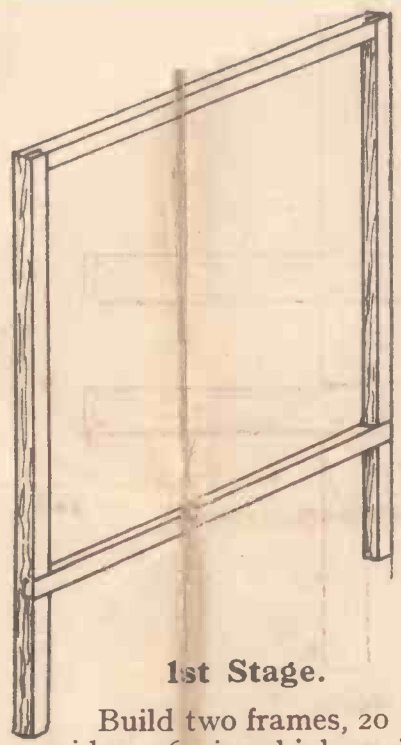
When a fault has developed in a set, it is necessary to test the components in order to locate the defective one. Although it is advisable to disconnect the parts to be tested, it is not always necessary to do so.

When the batteries or mains are disconnected and the valves are removed, a number of parts, such as fixed resistances and transformers, can be tested without unwiring them.

It is possible to test a wired part only when there is nothing in parallel with it, which is likely to affect the test. Thus, when a high resistance is connected across a condenser, the condenser cannot be tested for insulation, although the resistance of the leak can be found, if the condenser is good.

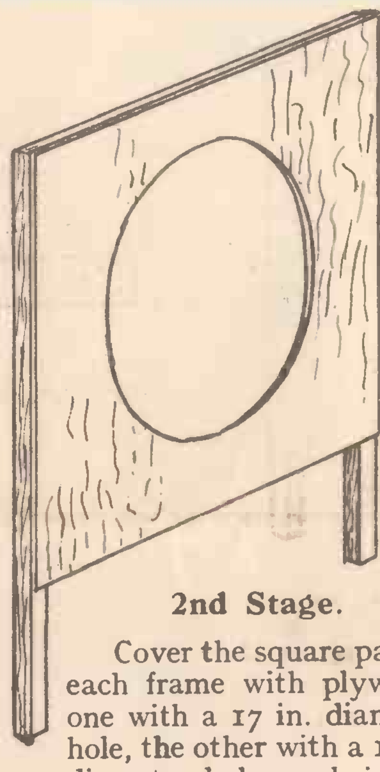
When a number of condensers are in parallel they can be first tested *en bloc* to see if any of them are faulty, and disconnected only if a fault exists.

DESIGN CHART FOR THE 'COMPLETE WIRELESS" DOUBLE CONE PORTABLE



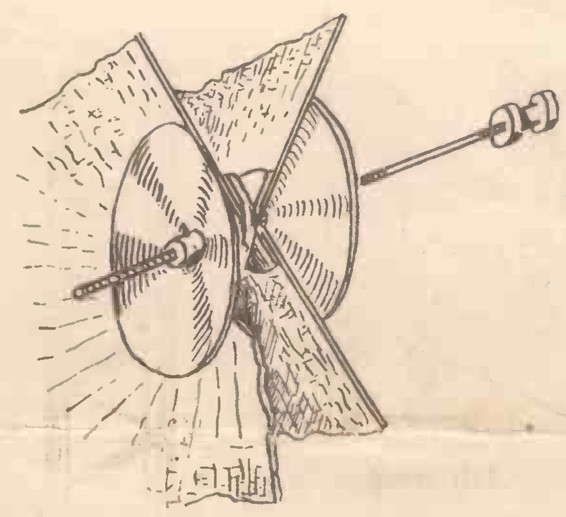
1st Stage.

Build two frames, 20 in. wide, 26 in. high, with halved or dowelled joints.



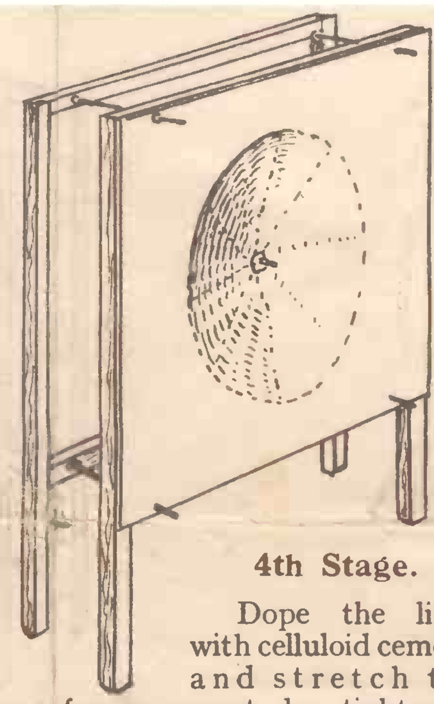
2nd Stage.

Cover the square part of each frame with plywood, one with a 17 in. diameter hole, the other with a 13 in. diameter hole, each in the centre of the plywood.



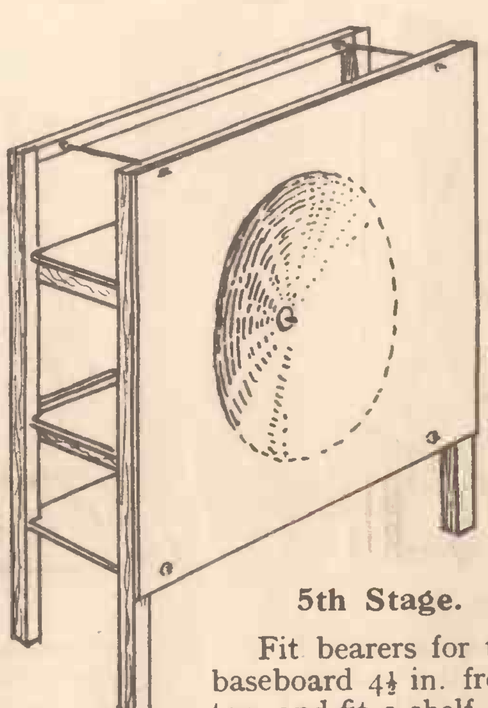
3rd Stage.

Cover the outer faces of the plywood with linen, connect the frames with four brass extension rods; fasten the linen together in the centre with the L.S. washers and spindle, as shown.



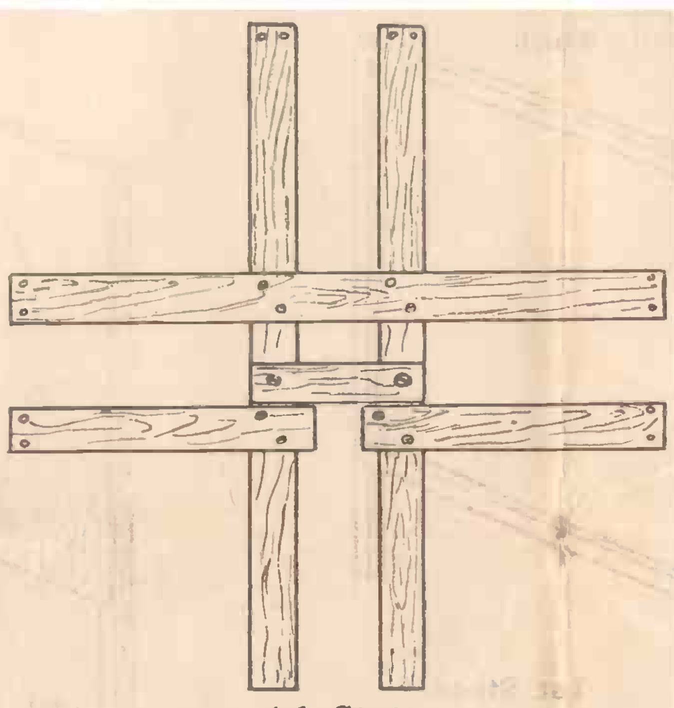
4th Stage.

Dope the linen with celluloid cement, and stretch the frames apart by tightening the nuts in the inside of the frames. Give three separate coats of dope and stretch the frames until they measure $5\frac{3}{4}$ in. wide from back to front.



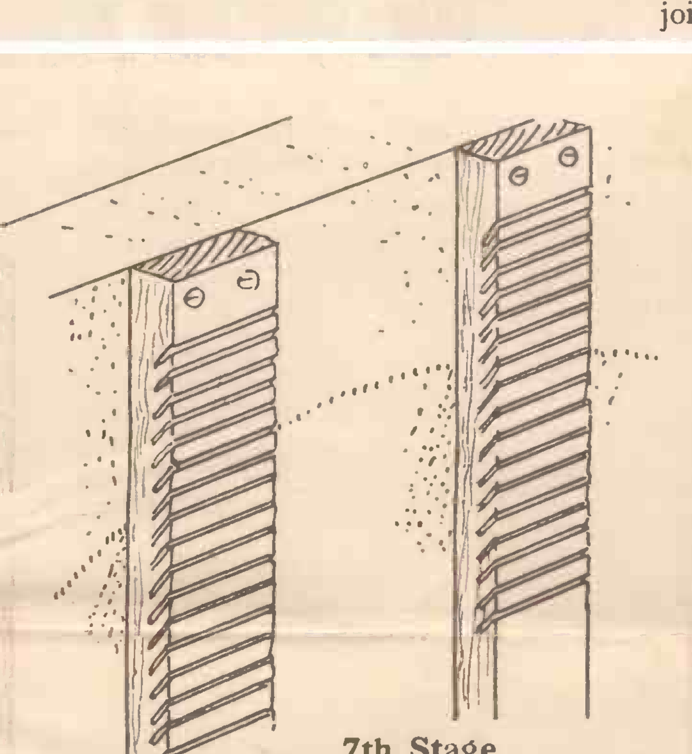
5th Stage.

Fit bearers for the baseboard $4\frac{1}{4}$ in. from top, and fit a shelf for the L.T. battery 13 in. from the top, and screw a board to the bottom framework.



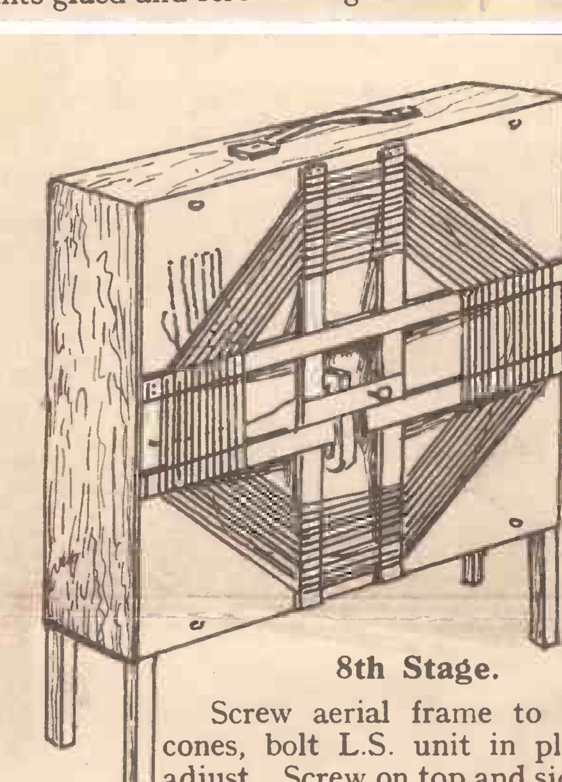
6th Stage.

Build the aerial frame as shown, 20 in. wide, 20 in. high, and $2\frac{1}{2}$ in. between the inner faces of the parallel battens. Add a cross-piece for the L.S. unit. Use halved joints glued and screwed together.



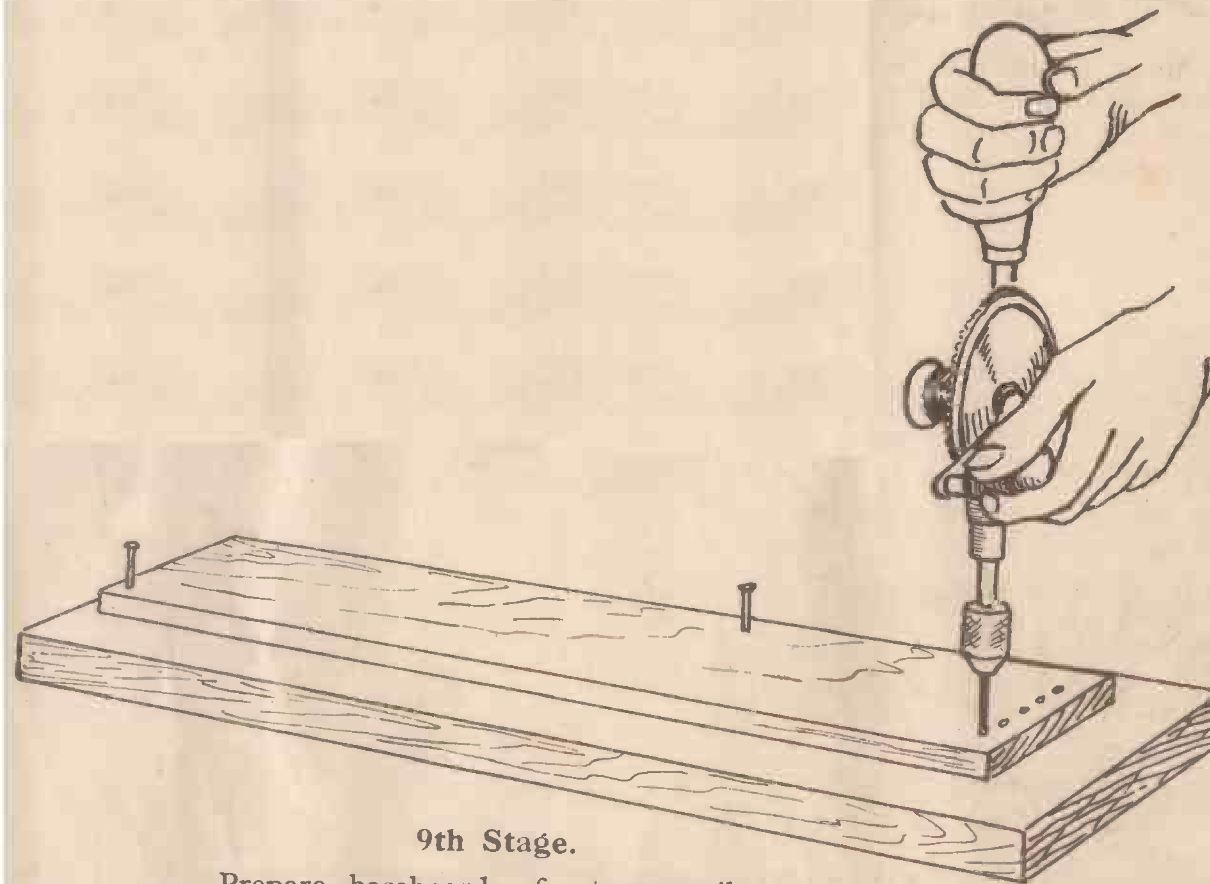
7th Stage.

Make 17 inward inclined saw-cuts across each frame batten, commencing $\frac{1}{2}$ in. from ends and spaced $\frac{3}{16}$ in. apart.



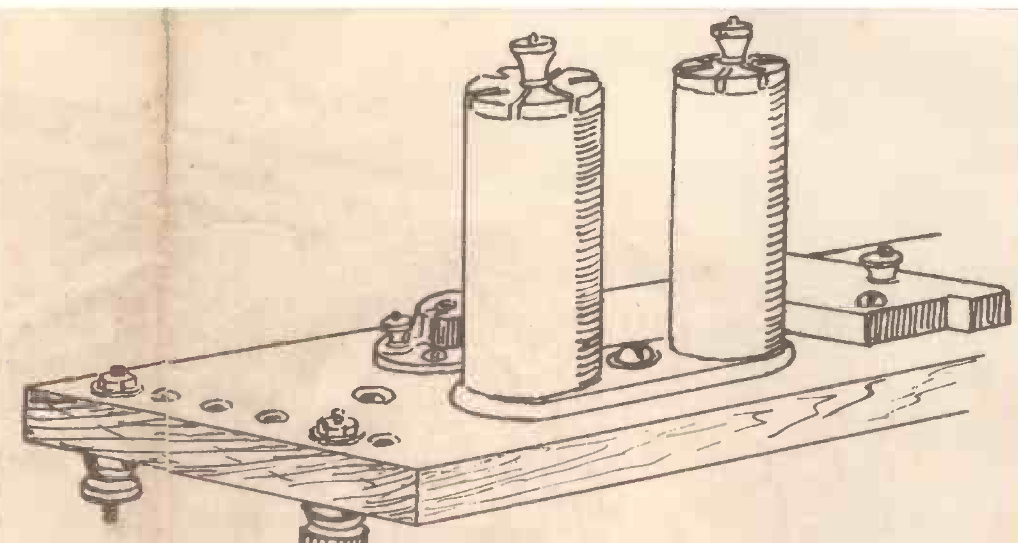
8th Stage.

Screw aerial frame to back of cones, bolt L.S. unit in place and adjust. Screw on top and side piece, hinge the door, and screw an ornamental fret to the face side. Wind the frame aerial.



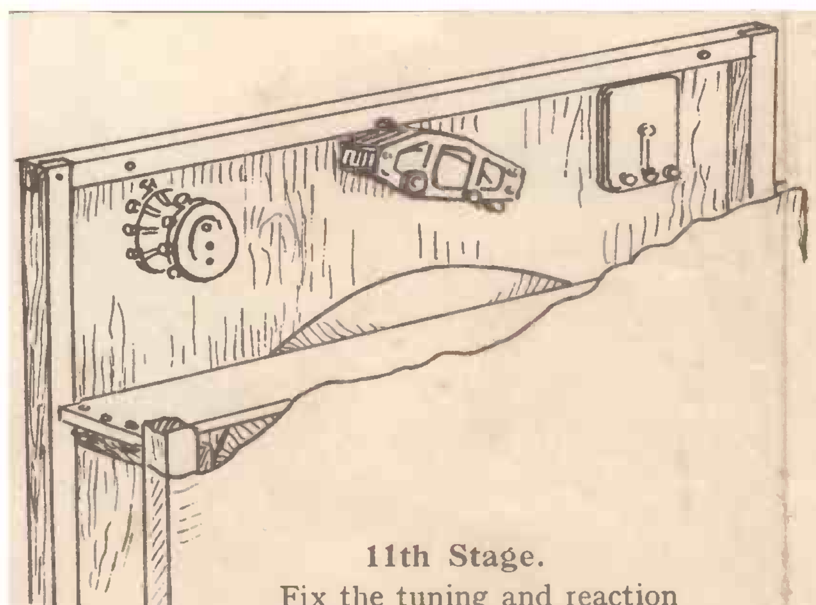
9th Stage.

Prepare baseboards, fix temporarily to rough piece of wood, drill holes for battery leads and terminals, countersink them each side, and sandpaper smooth.



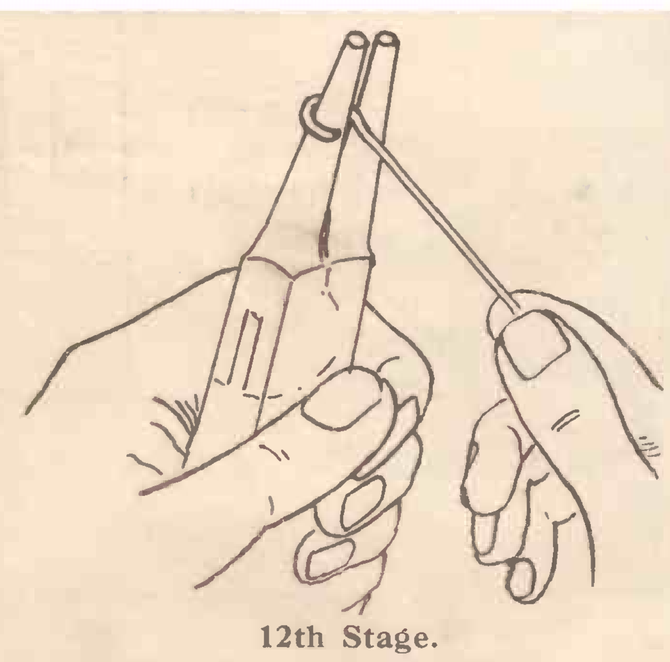
10th Stage.

Fit terminals to baseboard and screw components in place, following the arrangement shown below on the full-size Diagram.



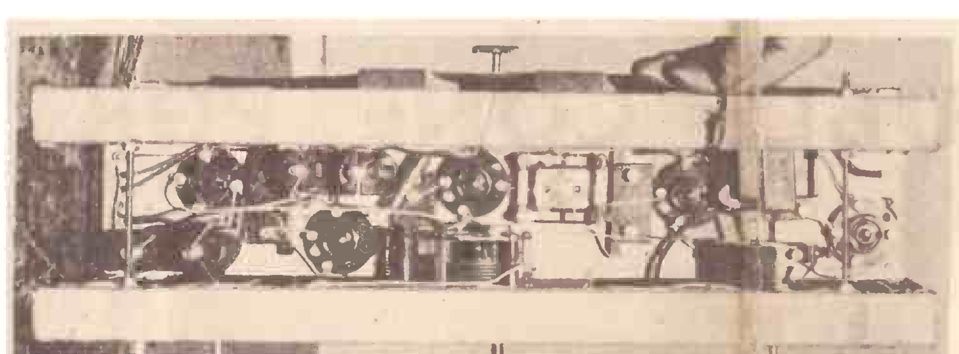
11th Stage.

Fix the tuning and reaction condensers and the combined wave-change and on-off switch to the front of the case above the baseboard.



12th Stage.

Form neat eyes on the ends of all wire-connecting links, then wire up the set as shown in the Uni-view Diagram.

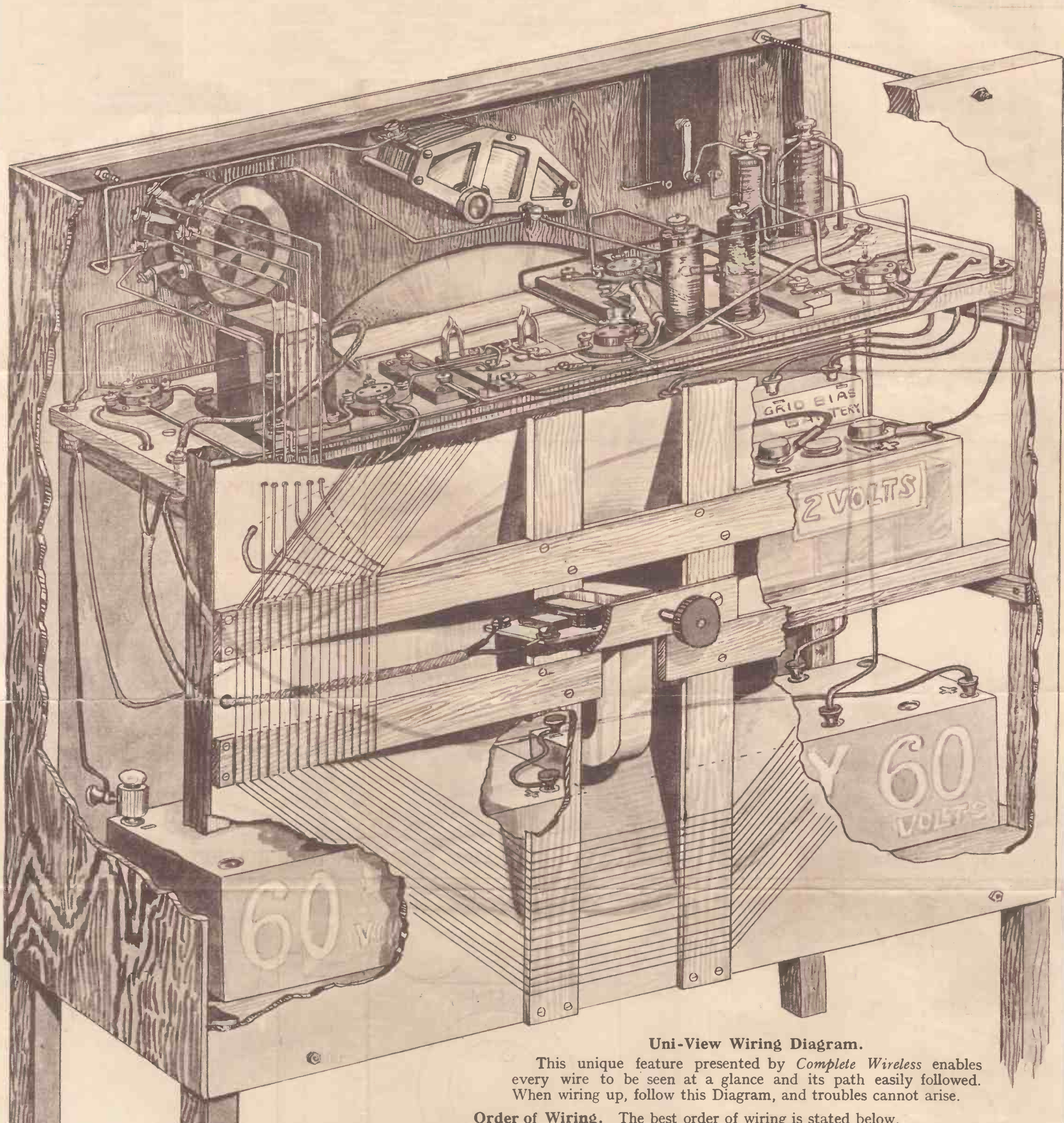


Components on Baseboard.

Here are seen the various components in place on the detachable baseboard, which facilitates the wiring.

Completely self-contained, this original design has been evolved and tested by the technical staff of *Complete Wireless*. It will receive numerous British and Continental stations at full loud-speaker strength, has a pleasant clear musical tone, is easy to tune, and inexpensive to make. The loud-speaker framework takes the place of the usual cabinet, and all components and batteries are housed in the space between the cones, as can be seen in the Uni-view Wiring Diagram.

Progressive stages of construction are clearly illustrated in the sketches, which show the whole process in 12 stages. The Uni-view Wiring Diagram shows clearly the path of every wire in the set, eliminating all trouble in construction.



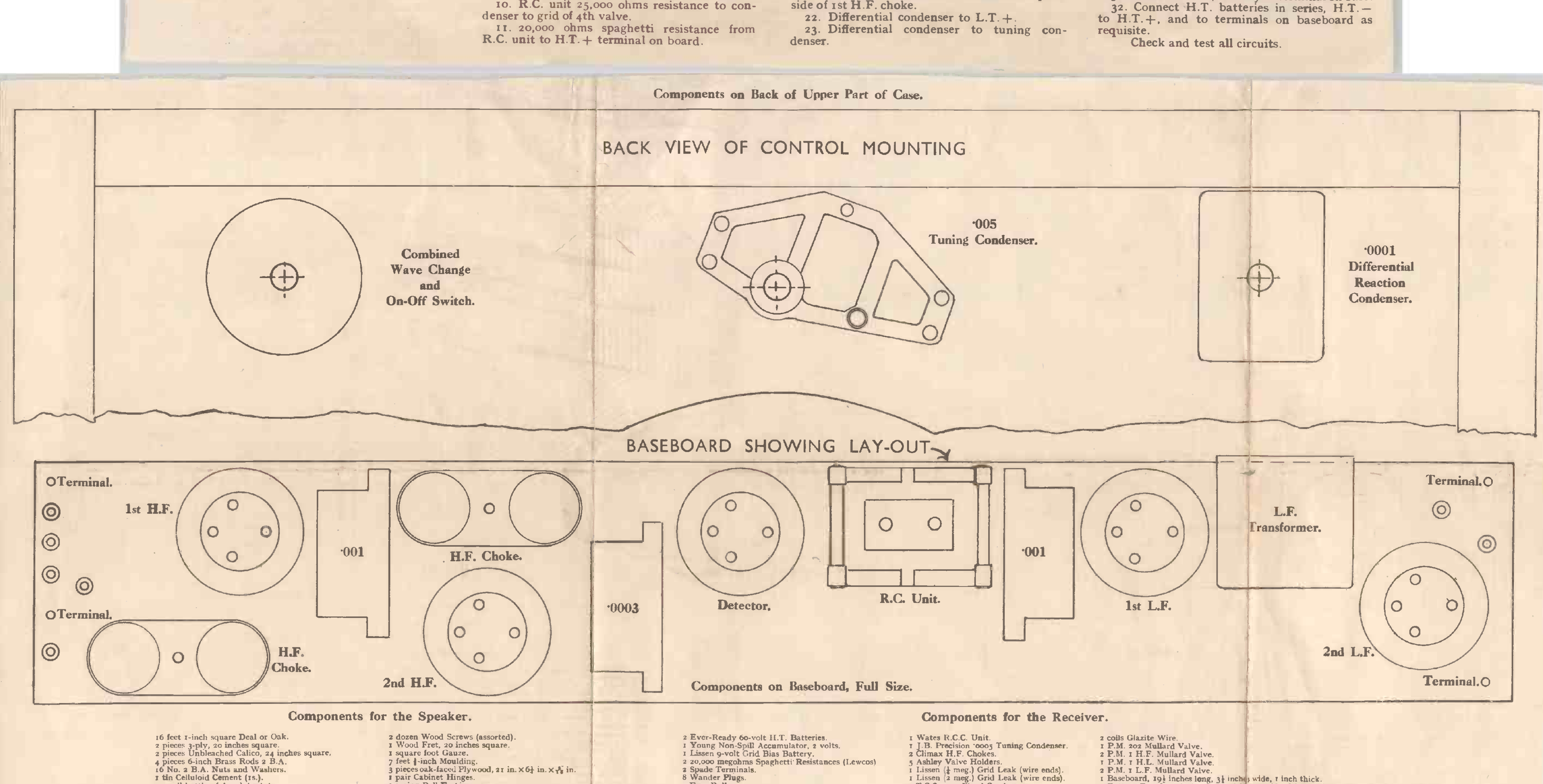
Uni-View Wiring Diagram.

This unique feature presented by *Complete Wireless* enables every wire to be seen at a glance and its path easily followed. When wiring up, follow this Diagram, and troubles cannot arise.

Order of Wiring. The best order of wiring is stated below.

1. Run L.T.+ to 5 valve holders and to by-pass condenser.
2. Run L.T.— to 5 holders and for switch.
3. 1st H.F. choke to plate 1st valve and by-pass condenser.
4. Condenser to grid of 2nd valve.
5. Fit ·25 MΩ resistance to grid and L.T.+ on 2nd valve holder.
6. Connect plate of 2nd valve to choke and grid leak condenser.
7. Grid condenser to grid of 3rd valve.
8. Float in 2 MΩ grid leak between L.T.+ and grid side of condenser.
9. Plate of detector valve to 2 MΩ resistance on R.C. unit condenser and to by-pass condenser.
10. R.C. unit 25,000 ohms resistance to condenser to grid of 4th valve.
11. 20,000 ohms spaghetti resistance from R.C. unit to H.T.+ terminal on board.
12. Grid bias No. 1 to R.C. unit resistance.
13. Grid bias + to L.T.— on 1st valve.
14. Grid bias — No. 2 to "G.B." on L.F. transformer.
15. Plate of 4th valve to "P." on L.F. transformer.
16. Grid of 5th valve to "G." to L.F. transformer.
17. H.T.+ up through hole in board to 1st H.F. choke.
18. H.T.+ terminal. 20,000 ohms spaghetti resistance to "H.T." on L.F. transformer.
19. Connect 2 H.F. chokes.
20. Insert in case and screw base to bearers.
21. Centre of differential condenser to plate side of 1st H.F. choke.
22. Differential condenser to L.T.+.
23. Differential condenser to tuning condenser.
24. Tuning condenser to No. 1 on switch.
25. Tuning condenser to No. 6 on switch.
26. Connect L.T. — from terminal on base to L.T.— and H.T.— batteries and to No. 8 on switch.
27. No. 7 on switch to L.T.— of 5th valve.
28. Connect switch to frame aerial: No. 1 to start of first coil, No. 3 to start 2nd coil, No. 5 to start third coil. Connect No. 2 to end first coil, No. 4 to end second coil, No. 6 to end of third coil.
29. Connect centre tap on aerial coil to L.T.+ on 4th valve holder.
30. Connect loud-speaker leads, one to terminal on base, one to plate of 5th valve holder.
31. Connect L.T.+battery to terminal on base.
32. Connect H.T. batteries in series, H.T.— to H.T.+, and to terminals on baseboard as requisite.

Check and test all circuits.



Components for the Speaker.

16 feet 1-inch square Deal or Oak.
2 pieces 3-ply, 20 inches square.
2 pieces Unbleached Calico, 24 inches square.
4 pieces 6-inch Brass Rods 2 B.A.
16 No. 2 B.A. Nuts and Washers.
1 tin Celluloid Cement (1s.).
1 small bottle of Amyl Acetate.
1 Ormond or Lissen L.S. Unit.
1 L.S. Extension Spindle and large Cone Washers.
1 tube of Seccotine.
2 dozen Wood Screws (assorted).
1 Wood Fret, 20 inches square.
1 square foot Gauze.
7 feet ½-inch Moulding.
3 pieces oak-faced Plywood, 21 in. × 6½ in. × $\frac{3}{16}$ in.
1 pair Cabinet Hinges.
2 spring Ball Fasteners.
1 carrying Handle.
2 pieces 1½ inch by 1½ inch oak, 20 inches long.
1 piece 1½ inch by 1½ inch, 6 inches long.

Components for the Receiver.

2 Ever-Ready 60-volt H.T. Batteries.
1 Young Non-Spill Accumulator, 2 volts.
1 Lissen 9-volt Grid Bias Battery.
2 20,000 megohms Spaghetti Resistances (Lewcos)
2 Spade Terminals.
8 Wander Plugs.
1 Fuse Bulb.
1 Fuse Bulb Holder.
1 Ormond S.M. Dial.
1 Telsen ·0001 Differential Condenser.
1 Junit Multi-Switch.
1 Lewcos 4·1 L.F. Transformer.
1 Wates R.C.C. Unit.
1 J.B. Precision ·0005 Tuning Condenser.
2 Climax H.F. Chokes.
5 Ashley Valve Holders.
1 Lissen (¼ meg.) Grid Leak (wire ends).
1 Lissen (2 meg.) Grid Leak (wire ends).
2 T.C.C. ·001 Fixed Condensers.
1 T.C.C. ·0003 Fixed Condenser.
100 feet Lewcos Frame Aerial Wire.
4 ounces 30 D.S.C. Wire.
12 feet Insulated Flexible Wire.
4 Telephone Terminals.
2 coils Glazite Wire.
1 P.M. 202 Mullard Valve.
2 P.M. 1 H.F. Mullard Valve.
1 P.M. 1 H.L. Mullard Valve.
2 P.M. 1 L.F. Mullard Valve.
1 Baseboard, 19½ inches long, 3½ inches wide, 1 inch thick.
1 Bottom Board, 20 inches long, 5½ inches wide, ½ inch thick.
1 Shelf, 6 inches long, 4 inches wide, ½ inch thick.
2 Shelf Supports, ½ inch diameter, 6 inches long.
5 feet ½-inch square Moulding.
5 Bearers, 1 inch wide, ½ inch thick, 3½ inches long.

A DOUBLE CONE TRANSPORTABLE RECEIVER

By A. PINK

A DOUBLE cone linen diaphragm loud speaker is well known to give excellent quality and will well pay for the extra trouble in constructing this type of loud speaker.

The set described below is built between the two cones, so that it may be used as a firescreen or transportable, easily carried from room to room or to the garden. It is easy to operate, neat in appearance, and will bring in a number of foreign transmissions as well as the home stations.

Fig. 1.—THE COMPLETED RECEIVER.

MAKING THE LOUD SPEAKER AND CASE WORK

Apparatus Required for the Cabinet and Speaker

16 feet 1-inch square deal or oak.
2 pieces 3-ply 20 inches square.
2 pieces unbleached calico 24 inches square.
4 pieces 6-inch brass rods 2 B.A.
16 No. 2 B.A. nuts and washers.
1 Tin Celluloid Cement (1*s.*).
1 Small bottle of Amyl Acetate.
1 Ormond or Lissen L.S. Unit.
1 L.S. Extension Spindle and large Cone Washers.
1 Tube of Seccotine.
2 doz. wood screws (assorted).
1 Wood Fret 20 inches square.
1 square foot gauze.
7 feet ⅝-inch Moulding.
3 pieces oak-faced plywood, 20 inches × 6 inches.
1 pair Cabinet hinges.
2 spring ball fasteners.
1 Carrying handle.
4 pieces 1½ inch × ½ inch oak 20 inches long.
1 piece 1½ inches × ½ inch oak 6 inches long.

First Make the Frames

First construct the two frames to hold the plywood. Half slot the crosspieces to the legs with a tenon saw and screw together. Dowelled joints may be used.

Cut out two circles in the centre of the plywood, $8\frac{1}{2}$ inches radius and $6\frac{1}{2}$ inches radius respectively. Screw the plywood to the frames.

Attaching the Calico for Cones

Completely cover the outside surface of the plywood with liquid glue and lay the calico squarely over the centres so that the overlap round the sides is 2 inches; this overlap can now be stuck down round the frames. When thoroughly dry place the two frames back to back and drill the holes through the top and bottom frames for the extension rods, 2 inches in from the sides. The centre holes for the spindle should be "buttonhole" stitched before fixing the washers to prevent tearing through when the cones are stretched apart. The washers can now be fixed in position and the calico given its first coat of dope.

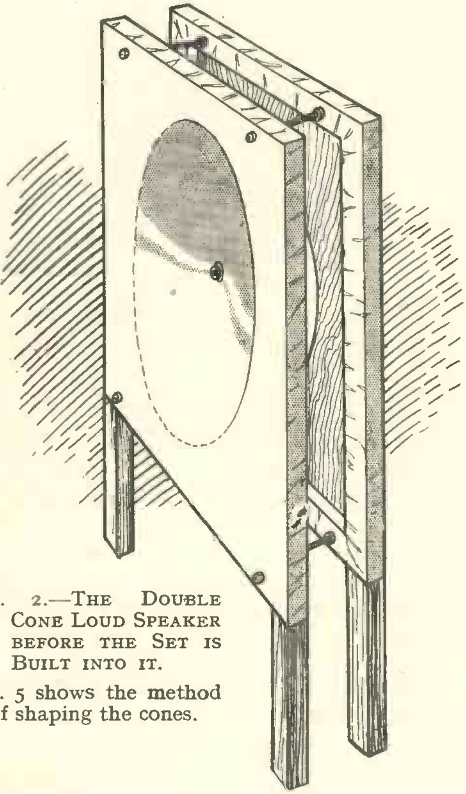


Fig. 2.—The Double Cone Loud Speaker before the Set is Built into it.

Fig. 5 shows the method of shaping the cones.

Coating Calico with Dope

Thin the celluloid cement with the amyl acetate and paint the calico with this solution evenly to $\frac{1}{2}$ inch beyond the circles.

Forming the Cones

While still wet, join the cone washers and carefully stretch the frames apart as far as the calico will allow. When thoroughly dry the cones may be given a second coat of dope, at the same time the frames again stretched apart another inch or more.

After the third coat the distance between the frames should be stretched to $3\frac{3}{4}$ inches, and between the plywood $5\frac{3}{4}$ inches.

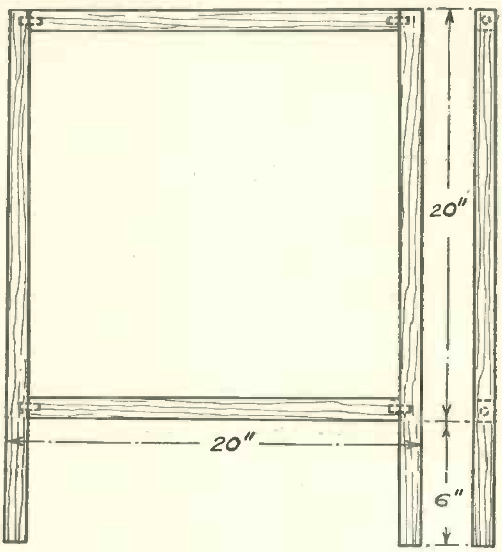


Fig. 3.—Details of the Frame.

Mounting Loud Speaker Unit

Battens, $\frac{1}{2}$ inch thick, should be prepared to take the speaker unit and the frame aerial wire, seventeen slots, $\frac{3}{16}$-inch apart, commencing $\frac{1}{2}$ inch from the extreme edge. The slots can be made with a tenon saw $\frac{1}{8}$ inch deep in a slanting direction towards the centre. Mount the unit to these battens so that the centre is true with the extension spindle. (See Fig. 10.)

Test for Final Adjustments

This should complete the loud speaker part of the apparatus, and if a friend's wireless set is available, a test for final adjustments can be given.

A distinct "plop" should be heard as the armature falls in position by turning the adjusting knob.

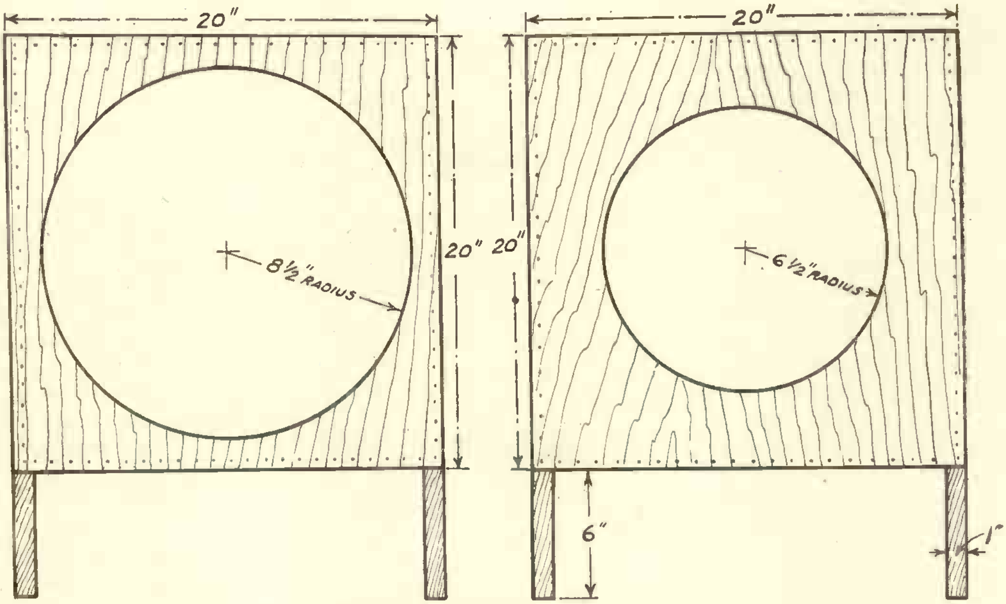


Fig. 4.—FRONT AND BACK OF LOUD SPEAKER.
The plywood square is secured to each of the wooden frames with ¾-inch gimp pins.

CONSTRUCTING THE RECEIVER

A straightforward five-valve Hartley circuit is chosen for its general results and low cost in construction.

Materials Required

The list of apparatus required is as follows :

2 Ever-Ready 60-volt H.T. Batteries.

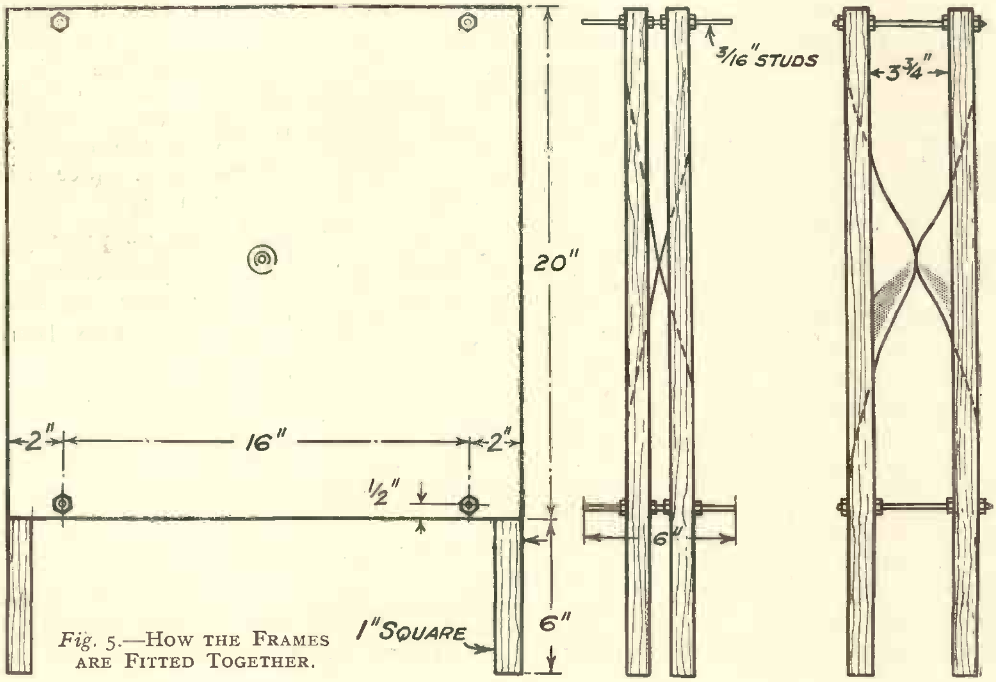


Fig. 5.—HOW THE FRAMES ARE FITTED TOGETHER.

1 Young Non-Spill Accumulator. 2 volts.
1 Lissen 9 volt Grid Bias Battery.
2 20,000 megohms Spaghetti Resistances.
2 Spade Terminals.
8 Wander Plugs.
1 Fuse-bulb.
1 Fuse-bulb Holder.
1 Ormond S.M. Dial.
1 Telsen ·0001 Differential Condenser.
1 Junit Multi Switch.
1 Telsen 3 : 1 L.F. Transformer.
1 Wates R.C.C. Unit.
1 J.B. Precision ·0005 Tuning Condenser.
2 Climax H.F. Chokes.
5 Ashley Valve Holders.
1 Lissen ($\frac{1}{4}$ meg.) Grid Leak. Wire ends.
1 Lissen (2 meg.) Grid Leak. Wire ends.
2 Lissen ·001 Fixed Condensers.
1 Lissen ·0003 Fixed Condensers.
100 feet Lewcos Frame Aerial Wire.
4 ozs. 30 S.W.G. Wire.
12 feet Insulated Flexible Wire.
4 Telephone Terminals.
2 coils Glazite wire.
~~1 P.2B. Marconi Valve.~~
~~2 H.L. 210 Marconi Valve.~~
x ~~1 210 H.L. Cossor Valve.~~
~~1 210 L.F. Cossor Valve.~~
1 Baseboard 19$\frac{1}{2}$ inches long, 3$\frac{1}{4}$ inches wide, $\frac{1}{2}$ inch thick.
1 Bottom board, 20 inches long, 5$\frac{1}{2}$ inches wide, $\frac{1}{2}$ inch thick.
1 Shelf 6 inches long, 4 inches wide, $\frac{1}{2}$ inch thick.
2 Shelf Supports, $\frac{1}{4}$ inch diameter, 6 inches long.
5 feet $\frac{3}{8}$ inch square moulding.
4 Bearers 1 inch wide, $\frac{1}{2}$ inch thick, 5$\frac{1}{2}$ inches long.

The Baseboard

A baseboard, 19$\frac{1}{2}$ by 3$\frac{1}{4}$ by $\frac{1}{2}$ inches, is necessary and should be made to rest on bearers fixed so that the top surface is as low as possible (at least 4$\frac{1}{2}$ inches) from the top without touching the cones. This baseboard is screwed to the bearers and can be fixed after the components are wired. It is drilled at the ends for the battery leads.

Fig. 6.—How the Frame Aerial is Wound.
The long wave winding lies underneath the medium winding.

Mounting Components on Baseboard

Mount the components as shown in the diagrams. The ·0005 tuning condenser and the ·0001 differential reaction condenser

x Valves should be 1, P.M. 202 ; 2, P.M.I.H.F. ; 1, P.M.I.H.L. ; 1, P.M.I.L.F. (all Mullard).

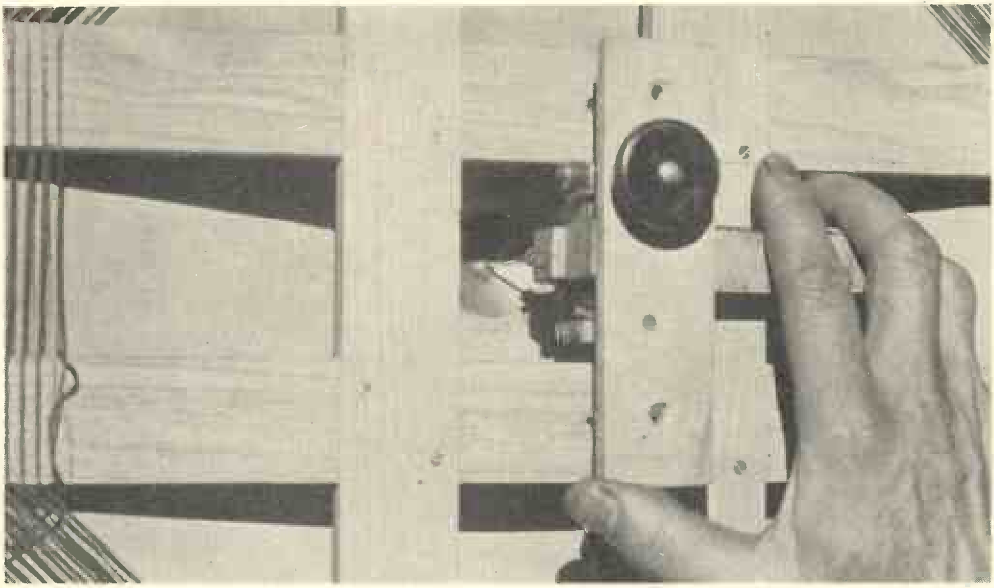


Fig. 7.—Fixing the Loud Speaker Unit to the Cone.

should not be mounted until most of the wiring is completed. These two condensers and the wave-change switch are assembled on the 3-ply front which forms the panel.

Wiring

Commence wiring the filament leads first. Flexible leads are used from the baseboard to the L.T. battery long enough to allow the accumulator to be removed easily for re-charging.

If these flexible leads are lettered or numbered it will certainly save time hunting for the various leads when the receiver is nearing completion.

The complete wiring may be carried out with Glazite, in which case soldering would be unnecessary.

Winding the Frame Aerial

The frame aerial may now be wound. Commence from the centre and wind in a clockwise direction seventeen turns of No. 30 silk-covered wire, leaving sufficient lengths each end to run to the change-over switch. Wind a second layer No. 30 in the same direction over the first. These two windings are shown in the diagram as Nos. 1 and 2, 5 and 6. They should be

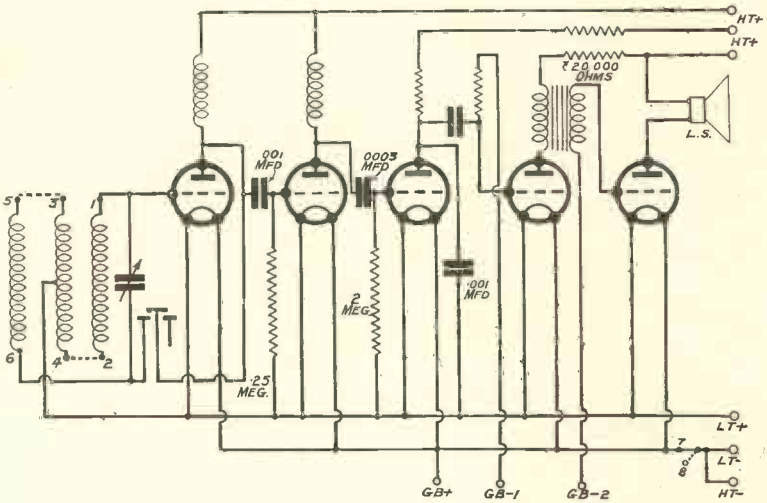


Fig. 8.—The Circuit employed for the Double Cone Transportable.

numbered with small slips of paper to prevent getting them mixed when attaching to the wave-change switch.

The thick frame aerial wire can now be wound on the top of these windings and in the same direction, that is, clockwise. This winding is number 3 and 4 in the diagram. The centre of this winding should be tapped and a lead run to connection No. 7 on the switch. The Nos. 7 and 8 connections act as a filament switch in the L.T. — lead.

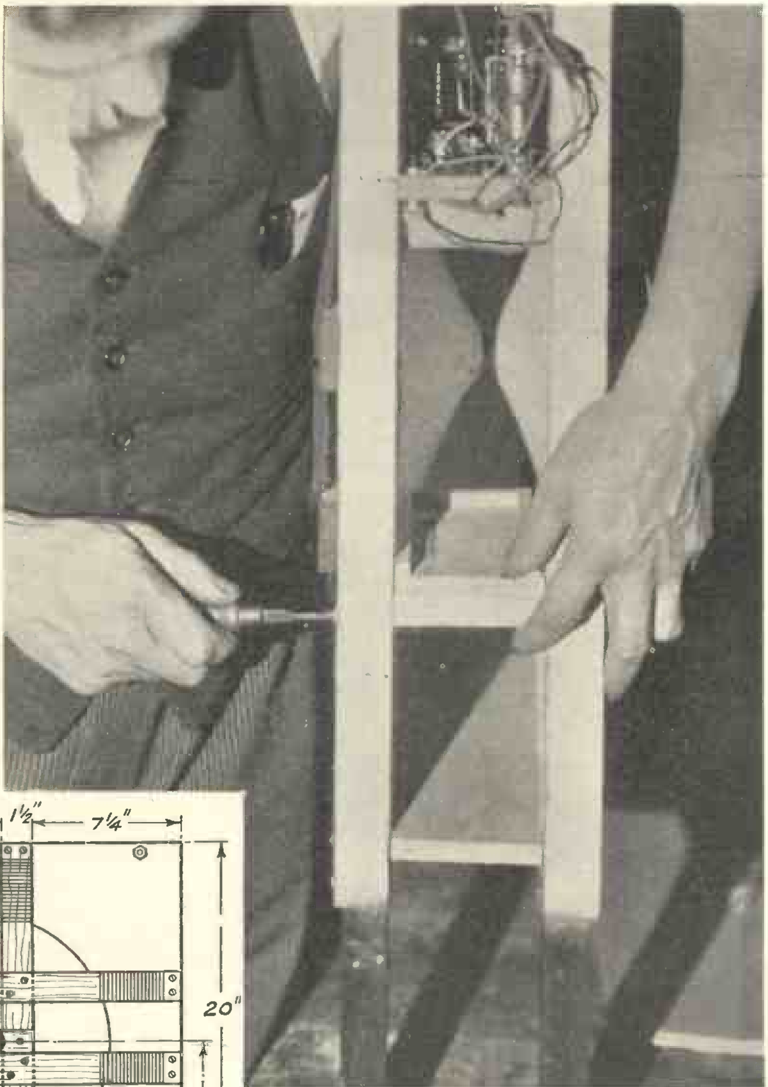


Fig. 9.—Fixing the Accumulator Platform in Position.
Showing also the lower high tension battery shelf.

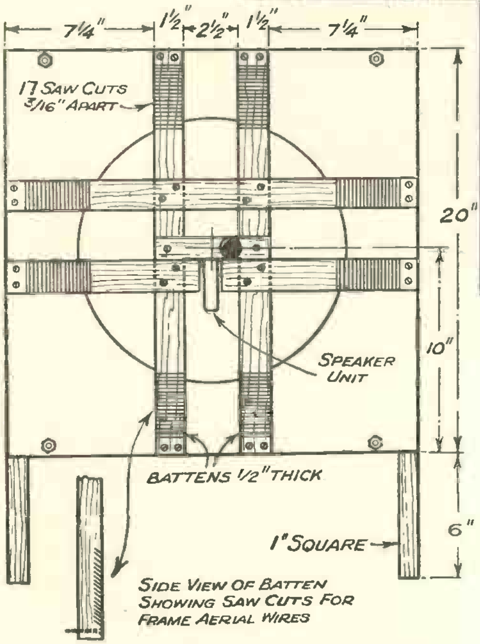


Fig. 10.—The Position of the Unit.
Showing how battens are secured to the frame.

Shelf for Batteries

A piece of board can be fixed at the bottom of the speaker to take the two 60-volt high tension batteries. A small platform to house the accumulator is built just above the H.T. batteries, and two small uprights will hold this in position.

Completing the Casing of Set

When everything has been tested out

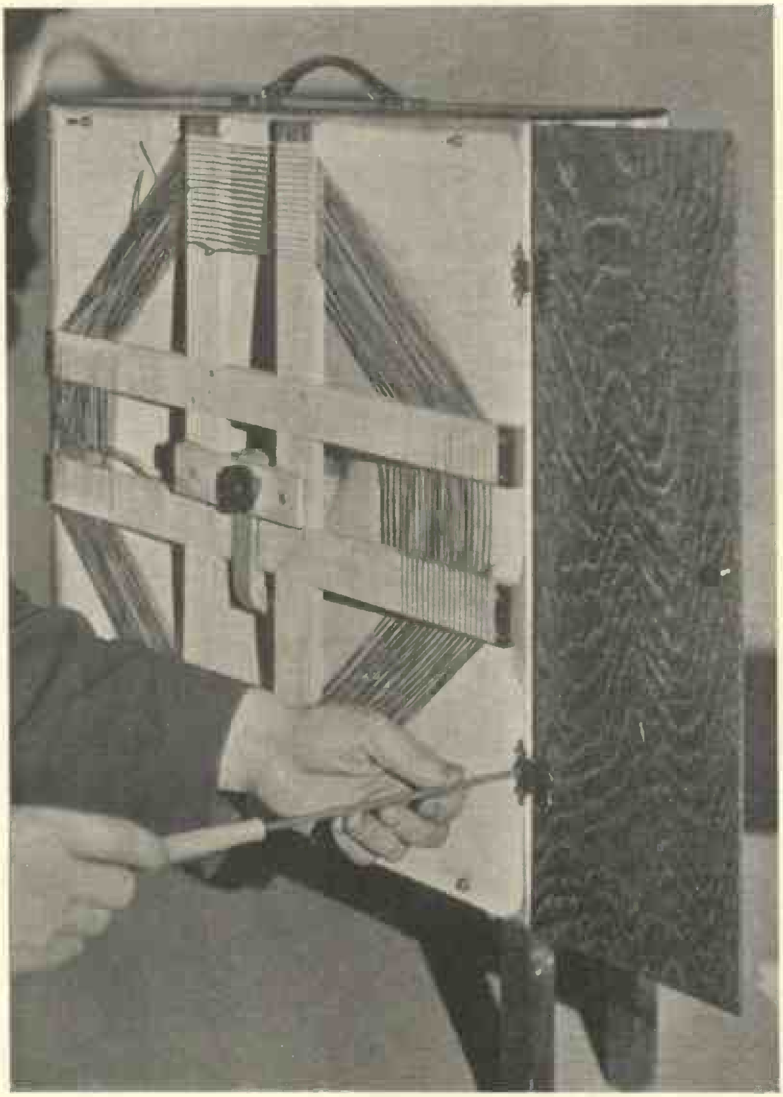


Fig. 11.—FIXING THE HINGED SIDE OF THE CABINET.

and satisfactory, the top and side pieces should be made. The side where the accumulator is placed should be hinged with two small hinges, and two small fasteners, preferably of the ball-and-socket type.

The top should be screwed down and the carrying handle fastened in the centre.

A fretted front with a moulding around the edge will give the whole apparatus a neat appearance, and this may be stained or otherwise according to taste.

Tuning

In tuning this type of receiver the most should be made of its directional properties, and 5 or 6 inches one way or the other may make all the difference in the strength of the incoming signal.

Careful adjustment of the reaction condenser is necessary when tuning-in distant stations, keep the set just on the oscillation point but do not let it howl. Adjust the values of H.T. current to secure the best results. If the set becomes unstable, reduce the H.T. on the first two valves.

What the Set will do

The special points about this novel set are, first, that it gives very fine reproduction owing to the fact that the large cone responds to the bass notes and the smaller cone to the treble. The selectivity is extremely good owing to the special form of frame aerial employed. In addition, the set, unlike many home-built sets, forms a handsome piece of furniture. It can be easily carried from room to room or out of doors. During the day Radio Paris and Daventry are easily received on long wave and most of the British stations on short wave. Many foreign stations can be received.

BATTERIES AND ACCUMULATORS

PRACTICAL NOTES ON THEIR CARE AND MAINTENANCE

By H. W. JOHNSON

The High Tension Battery

THE working life of a dry battery may be from six to three months, depending on the demand made upon it when using a suitable size of battery for the apparatus to be supplied with current.

If the battery fails under three months, then either the battery was old stock when bought, or the sal-ammoniac paste used in it has dried up, causing the internal resistance to be very high and the chemical activity of the cells to be greatly reduced.

What to do with Single Cells that are Faulty

Indications that the useful life of the battery is over may be obtained by testing the voltage of the battery with a high-resistance voltmeter when it is actually in use with a set. Individual cells of the battery which give little or no reading on the voltmeter should be short-circuited, as their presence in the circuit only adds to the resistance of the battery, and may produce crackling noises in the loud speaker or phones of a radio receiver supplied by the battery, due to bad internal connections in the faulty cells.

Fig. 1.—WHAT IS THE STATE OF THE ACCUMULATOR?

You can find out in a minute whether your accumulator is becoming exhausted by using the hydrometer. Insert the spout into the acid, suck some acid into the hydrometer, and then take the reading. By correctly acting on the readings obtained, a long life for the accumulator will be ensured.

ACCUMULATORS

If an accumulator is properly looked after and its working conditions are satisfactory, it will give no trouble during its working life. Accumulators which are used for working radio apparatus are often neglected, especially those used for H.T. supply, and consequently their life is shortened and their ampere hour capacity is reduced.

Charging a New Accumulator

The accumulator, when sent from battery makers, is usually without acid, and before it can be placed into service acid of the correct specific gravity must be added and the accumulator given its initial charge. Various methods are recommended by battery makers of giving the initial charge, and their directions given should be faithfully carried out.

Making up the Electrolyte

The electrolyte is a solution of pure brimstone sulphuric acid and distilled water made to a specific gravity of 1·2 to 1·25.

Acid must be Pure

The purity of the acid and the water is essential to the efficient working of the cell. The common impurities of commercial sulphuric acid are, copper, iron, arsenic, and nitrous compounds, and each of these attack the active material and the lead frames of the battery plates very strongly and very soon cause their destruction.

Pouring in the Solution

When making up the solution *always* add acid to water, as great heat is developed during the mixing process. The specific gravity of the solution is tested when cool and should be the exact figure given on the direction label on the accumulator. The electrolyte is then poured into the accumulator and should completely cover the plates. The plates will absorb some of the solution, and it will be necessary to add more to maintain the level. On no account should the top of the plates be allowed to become dry.

The Initial Charge

The charging current is adjusted to the correct value, making sure the positive pole of the supply is connected to the positive pole of the accumulator. The correct polarity may be ascertained by testing the supply terminals with pole-finding paper, the negative testing wire will give a stain on the paper. The initial charge should continue uninterrupted for the full period stated, and the accumulator is gassing freely. The voltage should be 2·6 when the charging current is passing. The voltage test when taken with the accumulator on open circuit is of little value.

A later article will deal fully with the various methods used for charging batteries commercially.

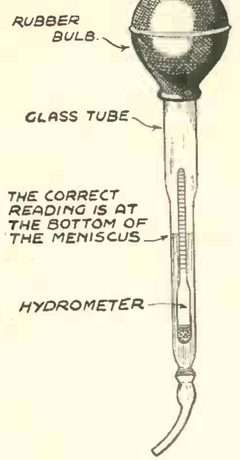


Fig. 2.—The Syringe Type Hydrometer

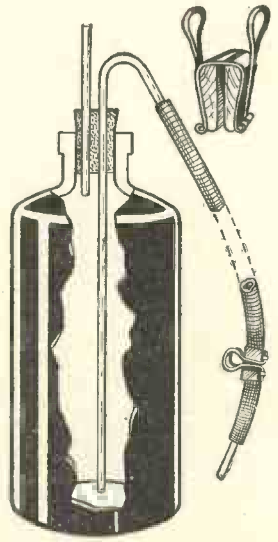


Fig. 3.—A Useful Appliance for the Wireless Man.

The syphon shown above will be found extremely useful for "topping up" batteries with distilled water, and is very simple to construct. Three pieces of ¼-inch glass tubing, some soft rubber tubing, a rubber stopper, and a strong paper clip are needed. To start the liquid flowing, blow gently through the small tube in the stopper, at the same time releasing the clip.

Colour of the Plates

The colour of the positive plates will be a deep chocolate and the colour of the negatives a blue grey when the accumulator is charged. The specific gravity of the electrolyte will have increased by about 0·5 per cent. during the charging process. Some battery makers recommend that the electrolyte be poured away after the initial charge and immediately refilled with new solution of the correct specific gravity. The accumulator is now ready for service.

The Limit to which an Accumulator should be Discharged

During the discharge of an accumulator the chemical activity of the plates is gradually reduced, and the specific gravity of the electrolyte falls. The plates now become covered with a film of lead sulphate which will be difficult to remove by the next charge if the discharge is taken too far. When the voltage of the accumulator has fallen to 1·8 the discharge should be stopped and immediately afterwards the re-charge should be commenced.

Effect of Neglecting to Charge a Discharged Accumulator

The electrolyte will attack the plates and produce a thick film of lead sulphate, and the specific gravity of the acid will be reduced. This film of sulphate cannot be removed by ordinary charging methods, and the ampere hour capacity of the accumulator will be permanently reduced. These remarks should be borne in mind with H.T. accumulators which are very often left in a discharged state and owing to the small amount of electrolyte in this type of accumulator, the electrolyte soon disappears, due to its chemical action on the plates and evaporation of the water in the electrolyte, causing the interior of the cells to be completely choked with lead sulphate.

Fig. 4.—Using Voltmeter to Test Accumulator.

Fig. 5.—Keep Plates covered with Electrolyte.
Topping up with distilled water.

ACCUMULATOR TROUBLES

The most frequent causes of accumulators giving trouble and the effects resulting from these causes are :—

(1) *Want of attention and Failure to carry out the Makers' Instructions.* — The effect of this neglect will cause unsatisfactory working of the accumulator, weak cells will not be detected when they first occur, and in time the plates of these cells will be ruined.

(2) *Excessive Overcharging.*— This produces positive active material in excess, leading to abnormal deposit of sediment, which in time will build up from the bottom of the accumulator container and short-circuit the plates. This incurs waste in using unnecessary charging current, and dissipates the electrolyte in the form of a spray which is lost if there is an opening in the top of the cell, and leads to a falling off in specific gravity when water is added to make up the deficiency. It also forms spongy lead on the negatives, leading to treeing across the plates and producing weak cells.

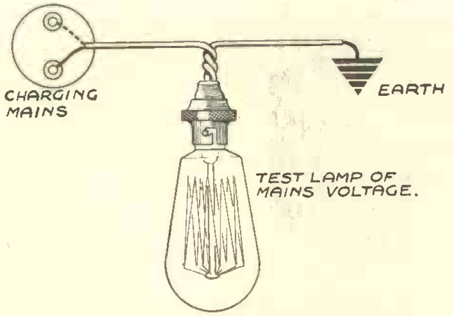


Fig. 6.—Finding the Earthed Side of the Battery Charging Mains.

If one of the charging mains is earthed, it is best to connect the battery on to it. A test lamp of the mains voltage is connected between each main and earth alternately. If the lamp lights brilliantly when connected to one main and not on the other, the main on which it does not light is the one which is earthed.

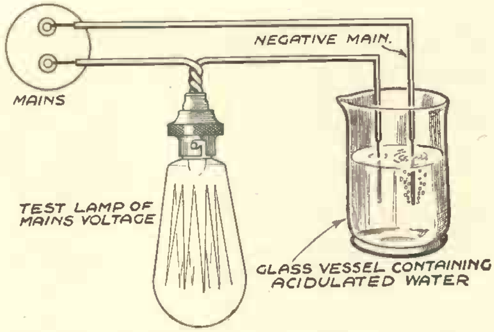


Fig. 7.—Finding the Polarity of the Charging Mains.

The polarity of D.C. or rectified A.C. mains may be tested by dipping the ends of the charging wires into a glass vessel containing water to which a teaspoonful of acid has been added. Bubbles of gas will be liberated from the negative charging wire. A test lamp of mains voltage should be connected in series with the circuit to prevent a short circuit.

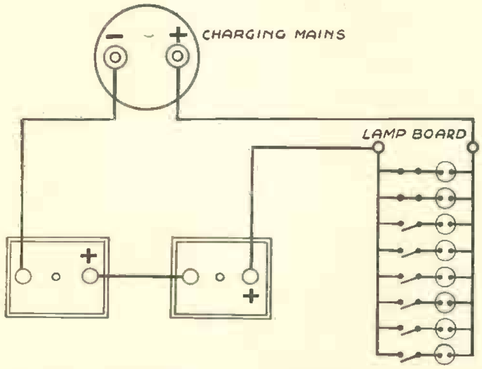


Fig. 8.—Connections for Charging Accumulator when the Negative Side of the Charging Mains is Earthed.

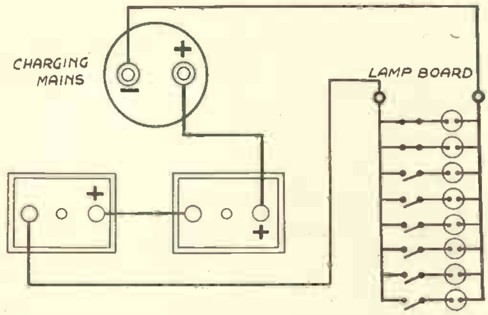


Fig. 9.—Connections for Charging Accumulator when the Positive Side of the Charging Mains is Earthed.

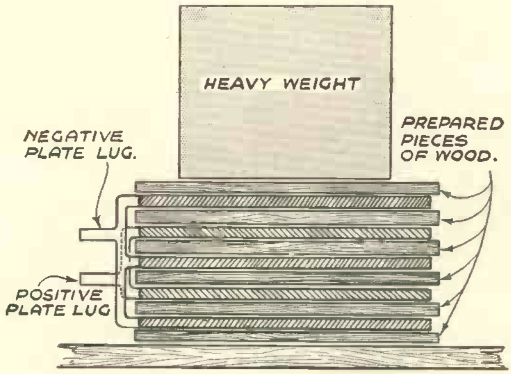


Fig. 10.—How to treat Swollen and Buckled Accumulator Plates.
Side view.

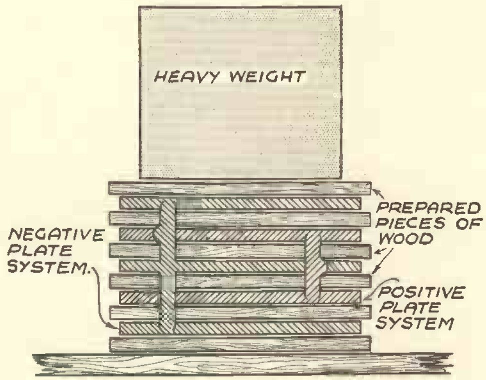


Fig. 11.—How to Treat Swollen and Buckled Accumulator Plates.
End view.

(3) *Running the Battery too Low on Discharge.*—The positive plates sulphate dangerously, the source from which buckling may arise. Makes the active material of the negative plates contract and so permanently lose capacity.

(4) *Under-charging.* — The electrolyte gradually decreases in specific gravity, and the plates sulphate, which, if neglected, it will be impossible to reduce.

(5) *Using Impure Acid or Unsuitable Water for Toppingup.*—The impurities will attack the plates, leading to their disintegration, or the impurities will combine with the electrolyte, producing a precipitate and cause the specific gravity of the electrolyte to be lowered. The precipitate will fill up the space below the plates which is ordinarily required for normal deposit of sediment, thereby causing more frequent cleaning out than would be otherwise necessary.

Fig. 12.—How to cure a Leaky Celluloid Container.

First empty the cell and carefully clean round the leak with the blade of a pocket knife or scraper knife.

Removal of Sediment from Accumulator Boxes

Carefully pour out the electrolyte into a suitable container and remove the cover of the accumulator box.

Removing the Cover

If the cover is made of bitumen it may be softened by passing steam from a kettle into the box. If made of celluloid, the joint between the cover and the sides is broken by inserting a thin-bladed knife. The cover and the plates are carefully removed so as to prevent the plates shorting with each other.

Replacing the Cover

The box is now flushed out with clean water and dried, and the separators from between the accumulator plates taken out and cleaned. The separators are replaced and the plates and cover are fixed again in the box. The joint between the box and cover is remade. A bitumen joint is made by softening the bitumen again and kneading it to the sides of the box ; a celluloid joint is made by running into the joint a solution of amyl acetate, acetone, and small pieces of celluloid which has been made to the consistency of syrup. Whilst the cover is removed, examine the terminal connections of the plates, and the condition of the insulating rubber bushes. These should be renewed if found faulty.

The electrolyte should be filtered and its specific gravity tested for correct strength before replacing it in the accumulator. The accumulator is now put on charge until it is gassing freely.

Treatment of Swollen and Buckled Plates

Prepare pieces of wood, ½ inch longer and ½ inch wider than the plates. The number required will be two more than the number of separators used in the accumulator, and their thickness equal to that of a separator. The prepared wood should be planed and perfectly flat. Pour off the electrolyte from the accumulator box and remove the plates. The separators are taken out from between the plates, and a prepared piece of wood placed between adjacent plates. A piece is also placed over the outside face of the first and one on the outside face of the last plate. The whole of the plates are now sandwiched between the prepared pieces of wood.

Placing a Weight on the Plates

The composite block of plates and wood is now placed on a flat surface and a heavy weight put on the upper piece of wood and left there for two or three hours. Great care should be taken not to dislodge the active material on the surface of the plates when removing the separators and inserting the prepared pieces of wood between the plates.

Remove the weight from the upper piece of wood and replace the pieces of wood between the plates with the separators. The plates and cover are fixed in position in the accumulator box, the electrolyte poured into the box, and the accumulator charged up until it is gassing freely.

Effect of Temperature on the Life and Capacity of an Accumulator

The maximum temperature at which an accumulator will work satisfactorily is 80° F. At higher temperatures the wear on the plates is excessive and their life will be considerably reduced. Working an accumulator at low temperatures reduces its capacity, but beyond this no harm will be done.

Treatment of Dry Plates

If the negative plates have for any reason become dry they will oxidise, and a long time will have to be allowed for re-charging. The positive plates will only require a comparatively short time for re-charging. The negatives should have part of their charge given with a dummy set of positives, and the remainder completed with the positives which will normally work with them.

Fig. 13.—CURING LEAKY CELLULOID CONTAINER.
Next apply a few drops of amyl acetate or acetone on the celluloid round the leak.

Putting an Accumulator out of Commission

Fully charge and then discharge the accumulator at the normal rate until the voltage of each cell has fallen to 1·84. The electrolyte is then poured out and replaced with pure water. Recommence the discharge, gradually reducing the resistance of the circuit until the accumulator voltage has fallen to zero. Now short-circuit the terminals of the accumulator and leave it twenty-four hours. Pour off the water and the plates will now take no harm for an indefinite period.

The wooden separators should be removed before finally storing the plates, and immersed in water until required again.

Putting the Accumulator into Commission again

Replace the separators between the plates and fit the plates and cover to the container. Prepare new electrolyte to the correct specific gravity and fill up the container with it to the working level. The charge should now be begun at the normal rate and continued without interruption until the accumulator is fully charged. This charge will take the same time as an initial charge.

"Topping" up the Accumulator

This is restoring the level of the electrolyte to the correct height with distilled water. The water obtained from rain-water cisterns, engine drains, peaty soil, and from hard water mains supply should not be used. Electrolyte should never be used to restore the level unless some has been spilled out of the accumulator.

A little vaseline smeared on the terminals will prevent any tendency to corrosion.

Fig. 14.—PATCHING LEAKY CELLULOID CONTAINER.

Also drop a little of the celluloid solution on to a patch of celluloid, with a piece of rag. The solution causes the celluloid to become sticky, in which condition the patch is placed in position and held until the liquid has set.

Fig. 15.—FINISHING OFF REPAIR TO LEAKY CONTAINER.

After fixing, paint the outside and the edges of the patch with some more of the celluloid sealing solution.

Jelly Acid Accumulators

The electrolyte in this type of accumulator is made in jelly form and should be kept thoroughly moist by the addition of a little distilled water before the commencement of each charge.

The electrolyte should be completely renewed every twelve months, and is done when the cells are in a fully charged condition. Attention to this will prevent "frothing," which often occurs with celluloid box accumulators after several months' use.

SERVICING

THE "EKCO" R.S.3, R.S.2, A.C., R.S.2, D.C., and S.H.25 RECEIVERS

Fig. 1.—How to remove the R.S.3 Receiver from the Cabinet, First Operation.
Turn the receiver upon its side and unscrew and remove the six cheese-head screws.

General Notes on all Models

In order to locate faults quickly, searching must proceed in a systematic manner, and for the guidance of the reader we would suggest the following order of test.

(1) Examine everything External to the receiver, such as aerial and earth wires, mains lead, wall socket, etc.

(2) Test to see if the detector and output valves are working by inserting a gramophone pick-up in the "pick-up" sockets and flicking the needle.

(3) Try changing each valve in the set in turn. Turn loud speaker adjustment knob (if there is one) to ascertain if loud speaker is working properly.

(4) Remove base-plate beneath the set and check all voltages with High Resistance Voltmeter having a resistance of 1,000 ohms per Volt.

(5) Examine all soldered joints for loose or bad connections. In case of doubt check wiring from blueprint.

(6) Test all "wound" components for continuity, and all condensers for shorts. The best test for fixed condensers is a "neon" lamp connected to a D.C. supply. Use a "Megger" if available.

This systematic search should reveal the cause of the trouble, and it may not be necessary to go through all the tests outlined above before the fault is located.

Fig. 2.—Second Operation.

Stand the receiver upright again and remove the control knobs and the back.

Fig. 3.—Third Operation.

Undo the hexagon nut holding the mains switch and push the switch back into chassis.

In ninety-nine cases out of a hundred system will locate the defect in a quarter of the time which would otherwise be taken.

INSTRUMENTS REQUIRED FOR TESTING

Very few meters are required, but they must be of first-class quality.

D.C. Voltmeter

The first instrument necessary is a multi-range voltmeter giving readings as follows :—

0–10 volts.
0–50 volts.
0–250 volts.

The meter should have a resistance of 1,000 ohms per volt. Any meter having a lower resistance than this may seriously damage the receiver.

A.C. Voltmeter

Secondly, a good quality A.C. voltmeter also of the three-range type. This is required for measuring mains input to receiver, A.C. voltages across the secondary of the mains transformer before rectification, heater voltages to indirectly heated valves, etc.

Tools

It is suggested that this list cannot be improved upon.

1 Universal electric soldering iron.
1 Ratchet screwdriver (6 inches).
1 Small screwdriver (4 inches).
1 Long screwdriver (10-inch thin bit).
1 Pair nut pliers.
1 Pair flat-nosed pliers.
1 Pair round-nosed pliers.
1 Pair side cutters.
1 Pair bolt cutters.
1 Set box spanners (0 B.A. to 8 B.A.)
1 Tap wrench.
1 Set taps (0 B.A. to 8 B.A.).
1 Small hand-brace.
1 Set drills 0 B.A. clearing to 8 B.A. tapping.
1 Dusting brush, 1 inch.
1 Duster.
1 4-inch smooth file.
1 Small reamer.
1 1 lb. small hammer.
1 ¾-inch cold chisel.
1 Knife.

Instruments for Measuring Resistance

Thirdly, some instrument for measuring resistance, such as a milliameter connected in series with a battery, and an

Fig. 4 (Right).—Fourth Operation.

Undo the four dome headed bolts holding the metal grille in position. The grille can then be easily removed.

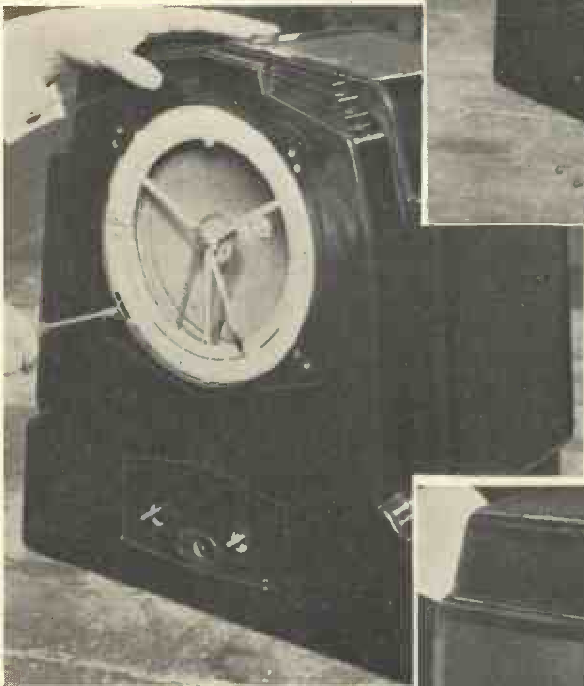


Fig. 5 (Left).—Fifth Operation.

Remove the four countersunk bolts which hold the loud speaker baffle in position

Fig. 6 (Right).—Final Operation.

The cabinet can be withdrawn by standing in front of the receiver and pulling it towards you, as the chassis stands upon four rubber feet which lift it well clear of the surface.

Ohmmeter, "Avometer," etc.

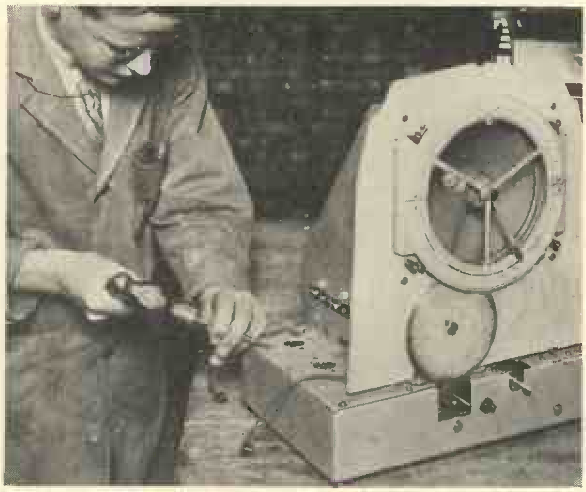


Fig. 7.—How to remove the Rivets.

A hammer and cold chisel should be used. Place the receiver chassis in a firm position and hold the chisel with the blade against the head of the rivet, and give the hammer a smart tap. Another method is to use a very flattened pair of side cutters and nip the head of the rivet. All rivets for securing components may be replaced with 4 B.A. nuts and bolts, and a small split (lock) washer should be placed over the bolt before the nut is tightened down. This is useful to remember when reassembling.

Headphones for Tracing Continuity

Fourthly, a pair of headphones. These are most useful for tracing continuity in circuits, and when used for this purpose a 1½-volt cell should be permanently connected in series with one earpiece. When the phones are in use for testing continuity, as soon as the circuit is completed a click will be heard, due to the current from the battery passing through the component being tested and also through the earpieces themselves. If no click is heard,

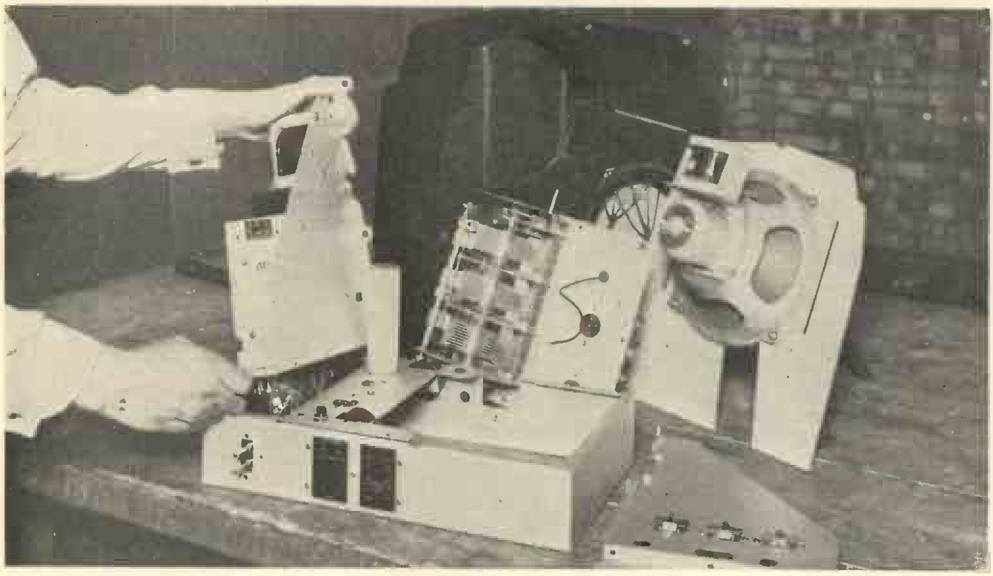


Fig. 8.—The Units being Dissembled.

The chassis consists of four main component units, the H.F. section, the detector section, the power pack and the loud speaker and dial assembly. Should it be necessary to remove any one section the scale and pointer mounting must be removed first and then the loud speaker and baffle. The H.F. panel or power pack may then be removed, but it is impossible to remove the detector panel before the H.F. panel has been removed. Time will be saved if this is borne in mind.

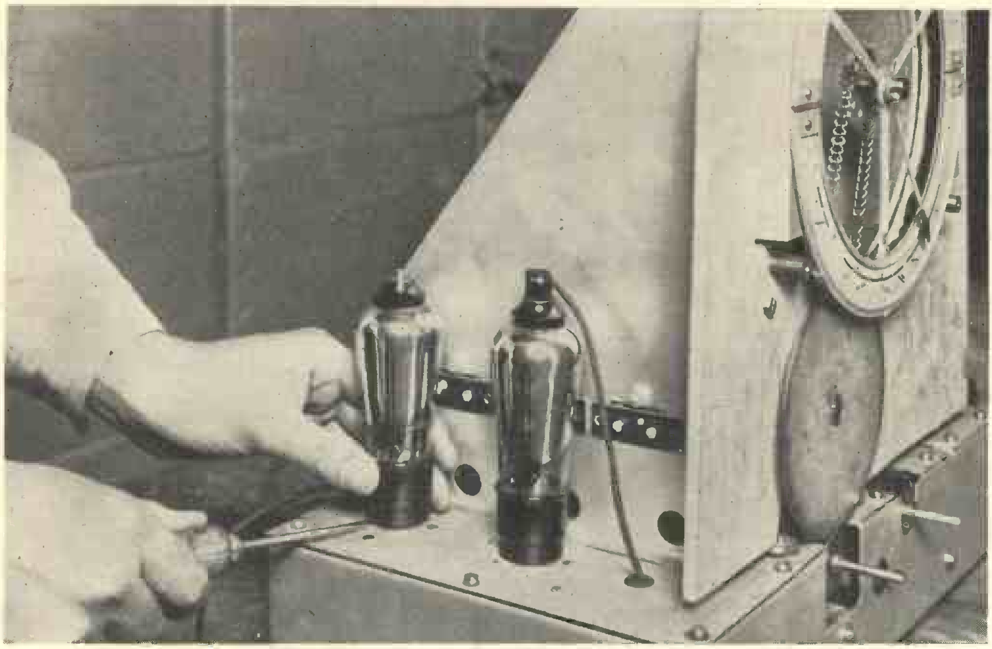


Fig. 9.—METHOD OF WITHDRAWING VALVES.

These should be inserted or removed without " wriggling." Microphonic reaction is often caused by one of the screened grid valves. The moulded anode connectors of the screened grid valves should be examined to see that not only does the metal insert make good contact with the flex but also that no bare wire is exposed. It is equally important that leads taken to the small plugs which are inserted in the back of the receiver are securely fixed into these plugs by being tightened with pliers.

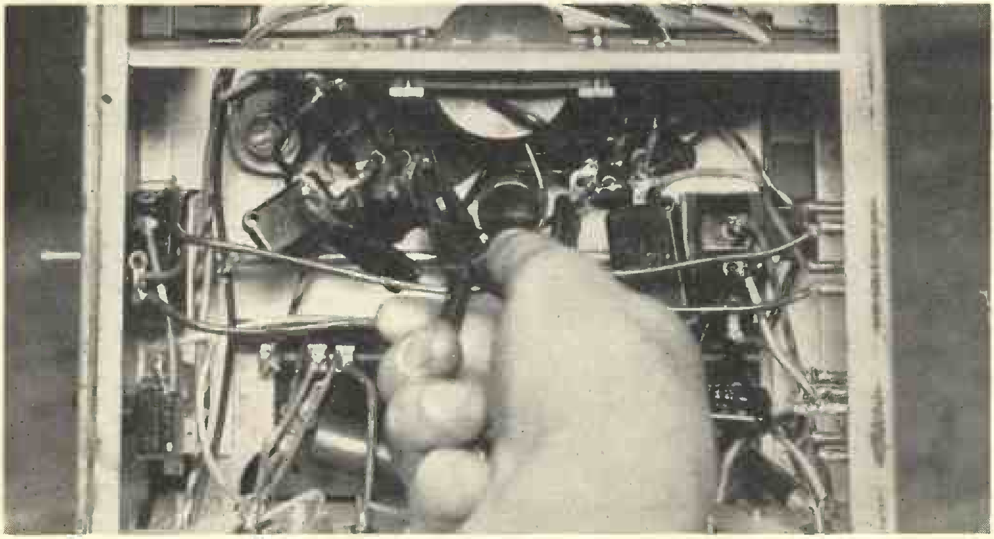


Fig. 10.—HOW TO TIGHTEN VALVE SOCKETS WITH CURVED PLIERS.

The best tool for squeezing the sockets is a pair of long round-nosed pliers with the ends bent at right angles. If the socket is gripped with these and slight pressure employed, then contact can be restored. It is essential, however, that the valve holders should not be subjected to any more wear than is absolutely necessary.

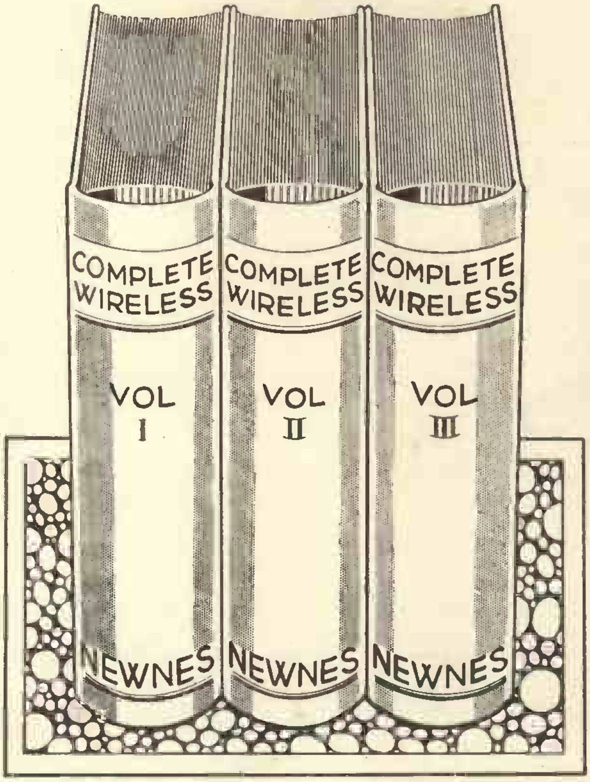
IMPORTANT NOTICE TO READERS

THE fact that you have purchased Part I. of this publication shows that you are personally and directly interested in the practical side of wireless reception. We will go further and say that a more intimate knowledge of modern wireless practice has a definite cash value to you. In purchasing this first part you have secured the opportunity of obtaining for a trifling cost a complete and up-to-date work on this important and expanding industry.

We can say with confidence that you will find it well worth while to purchase the complete set of parts as they are issued. Read through the list of contributors below, and you will get a very good idea as to the standard of excellence of this work.

Remember that the aim throughout has been to keep the treatment simple and practical, as well as technically sound.

These three handsome volumes containing more than 1,000 illustrations and many useful charts and tables can be obtained at trifling cost.



If you wish to secure this valuable work, which may be worth pounds to you, fill in the order form on page iv. and hand it to your Newsagent to-day.

General Editor: EDWARD MOLLOY. Advisory Editor: RALPH STRANGER.

A FINE LIST OF CONTRIBUTORS

Sir Oliver Lodge, M.I.E.E., D.Sc., F.R.S.

Sir John Ambrose Fleming, Kt. M.I.E.E., M.A., D.Sc., F.R.S.

N. Ashbridge, B.Sc., M.I.C.E.
Leslie McMichael, A.M.I.E.E., F.Inst.R.E.
F. H. Haynes.

J. Robinson, D.Sc., Ph.D., M.I.E.E.
S. R. Mullard, M.I.E.E., M.B.E.
A. E. Watkins.

H. E. J. Butler.
Harley Carter.
H. H. Dowsett.
E. W. Hobbs.
H. W. Johnson.
C. H. Hayward
L. D. Macgregor.
A. Pink.
C. A. Quarrington.
G. H. Watson.
J. H. A. Whitehouse.
F. Preston.

A Fine Investment

ARE YOU A WIRELESS ENTHUSIAST?

We realise that it would not be an easy task to satisfy the very high standard which you expect in a wireless publication. We believe, however, you will find that this new work is exactly the kind of wireless publication for which you have been looking. It will deal with the whole theory of wireless from the very simplest principles up to the most advanced stage (but please do not expect to find advanced theory in the early numbers). It will show you the most up-to-date practice as exemplified in the fine commercial sets which have been placed on the market recently. It will show you the possibilities of short-wave work, and will contain many useful designs for constructing experimental apparatus of all kinds.

FIVE REASONS WHY YOU

1. **Because it explains the theory and principles**
2. **Because it contains many new designs by the**
3. **Because it is authoritative and yet easy to u**
4. **Because it gives you the expert advice of ove**
5. **Because when completed it will be worth mu**

ARE YOU ON THE DISTRIBUTION SIDE?

If so, you will find this work invaluable. It contains authoritative servicing instructions for all the sets now on the market—His Master's Voice, Pye, Ekco, Columbia, Marconiphone, are just a few of the outstanding names. Full circuit details and data are given, and in nearly every case we have obtained splendid photographs, showing how the servicing should be carried out.

The man in the industry will have no difficulty in realising the value of a simple exposition of the underlying principles embodied in present-day receiving sets. These principles have been dealt with thoroughly by Ralph Stranger, in such a way that they can be readily understood by the practical man.

FILL IN THE ORDER FORM OVERLEAF TO-DAY AND MAK

for the Practical Man

ARE YOU ON THE MANUFACTURING SIDE?

Every year many thousands of new broadcast licences are taken up. Over 5,000,000 receiving sets are already in use. The scope for progress on the manufacturing side of the industry is likely to increase. In no other industry is manufacture influenced so readily by advances in theory and new inventions and discoveries. *No one can hope to hold his own for long on the manufacturing side unless he has a thorough grounding in fundamental theory.* The well-read man will be able to visualise the possibilities of a new discovery much more accurately than the man who has only a rule-of-thumb knowledge of wireless practice. This is why the new "Complete Wireless" will be indispensable to everyone engaged on this side of the industry.

SHOULD BUY THIS WORK

of wireless in a way that you can understand.
est designers.
rstand.
twenty wireless specialists.
more than it has cost you to purchase it.

SET BUILDING

No doubt you have already built several sets for yourself and for your friends or customers. In the "Complete Wireless" we shall show you many novel ideas in this direction. The keynote of the constructional articles is "Sets that are Different." We have also evolved a particularly convenient method of showing the wiring details and layout of the components in one diagram.

A Portable Set Giving Moving-Coil Quality Reproduction, a Pre-Tuned Wireless Set which will enable the lady of the house to switch on any four stations at will, a Screen-Grid Pentode-Two giving maximum performance for a 2-valve battery-driven set, are a few typical examples of the items which will be included.

SURE OF OBTAINING YOUR COPIES OF THIS FINE WORK

OUTLINE OF THE WORK

Wireless Theory Made Plain

Current Electricity—How it is Produced and What it Will Do.
Static Electricity—How it is Produced and Some Effects.
Current Voltage and Resistances in Wireless Circuits.
The Meaning of Inductance, Capacity and Impedance.
Primary Batteries.
Secondary Batteries.
Aerials.
Coils and Condensers.
The Tuning Circuit.
Band Pass Tuning.
Rectification and Rectifiers.
Valve Detection—Anode Bend—Grid Leak.
Valves—Screened Grid—Pentode—Bigrid—Variable Mu.
The Transformer and the Choke.
High Frequency Amplification.
Low Frequency Amplification.
Telephones and Loudspeakers.
Modern Receiving Circuits.
Stenode Circuit.
Autotone Circuit.
Superhet Circuits.
Gramophone Pick-Ups.
Wireless Diagrams.
The Mathematics of Wireless.
Transmitting Circuits.

Design, Construction and Experimental

Tools Used in Wireless Work.
Wires and Soldering.
Lay-out of Components.
Coil Winding Appliances.
Ebonite Working.
Metal Screens and Boxes.
Wiring Lay-out.
Resistances, Potentiometers and Grid Leaks.
Step-up and Step-down Transformers (L.F.).
Aerials, Earths and Counterpoises.
Coils.
High Frequency Amplifying Stages.
Low Frequency Amplifying Stages of all Types.
Telephones and Loudspeakers.
Volume Controls.
Mains Units.
Portable Receivers.
Radio-gramophones and Pick-ups.
Shortwave and Ultra Shortwave Receivers.
H.F. and L.F. Transformers.
H.F. and L.F. Chokes.
Anode Resistances.
Battery Charging Boards.
Lightning Arresters, Solenoid.
Condensers, Fixed and Variable (of all types, including the differential condenser).
Design of Tuners.
The Detector (Grid Leak Rectification, Anode Bend and Push Pull).
The Output Circuit.
Loudspeaker Extension Systems and Plug and Jack Control.
Method of Designing a Complete Receiver with an Example of a Four-valve Receiver.
The Wave Meter.
Wireless Cabinets.
Superheterodyne Receivers.
Frequency Controls.
Building a Superheterodyne Seven-valve Receiver.
Shortwave Work.
Television Apparatus.
Radio Controlled Models.
Home Recording, the Blattnerphone.
Receiving Pictures by Wireless.
Wireless Relaying.
Acoustico-electrical Control at Short Distances (robots).
Wireless Automatic Call Device.
A Receiver for a Motor Car.
Photo-Electric Burglar Alarm.
Public Address Systems.
Radio Compasses—Direction Finding.
Electrical Data and Wireless Formulæ Design Curves.
Wireless as a Career.

Maintenance and Servicing

Tracing Faults.
Service Man's Kit.
Locating Valve Faults.
Loudspeaker Faults and Remedies.
Charging of Accumulators.
Mains Supply Units.
Atmospherics and Interference.
Servicing H.M.V. Receivers and Radiograms.
Servicing Pye Receivers and Radiograms.
Servicing Gramophones.
Servicing Columbia Radiograms.
Servicing Ekco Receivers.
Servicing Cossor Receivers.
Servicing Marconiphone Receivers, etc., etc.

Cut along this line.

ORDER FORM

To .... *Newsagents.*

Please reserve for me each week one copy of "COMPLETE WIRELESS" and

Cross out which does not apply. { deliver it to my address below.
I will call for it.

Name ....

Address ....

....

PART 2 READY SEPTEMBER 23rd. **ORDER YOUR COPY TO-DAY**

vi

This article on "Servicing EKCO Receivers" is continued in Part 2. Ready September 23rd. Order your copy to-day.

BROADCASTING HOUSE

AN ILLUSTRATED DESCRIPTION

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

This Part Contains

FREE CHART

FOR

PEDESTAL RECEIVER

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

1/-

Part 2

IN ABOUT 24 WEEKLY PARTS

Fig. 11.—A POSSIBLE FAULT WITH THE GANG CONDENSER.

When it is suspected that the drive is slipping, first examine the switch to see that it is greased and has a sufficiently smooth action so as not to throw a heavy load on the condenser drive. The photograph shows the cam being greased. A convenient method is to use a match stick.

Fig. 12.—METHOD OF ADJUSTING TENSION OF CHAIN DRIVE.

The chain tension should be adjusted by setting the pointer and scale mounting up and down. Care should be taken to see that the scale mounting does not show above or below that part of the feet marked "gram." If the latter is the case, the length of the chain must be adjusted by removing or inserting a link.

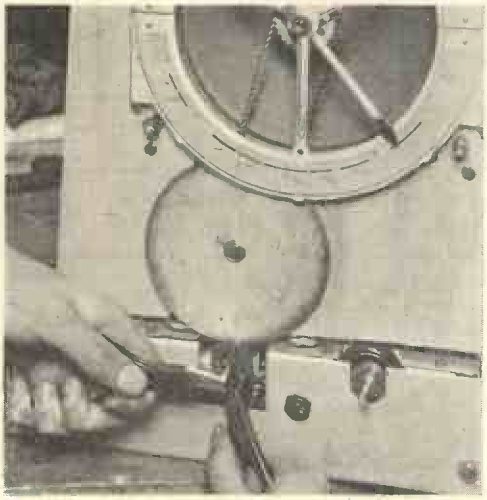


Fig. 13.—TIGHTENING UP THE DRIVE WASHERS.

It is essential to make sure that the nut on the drive washers is really tight. This nut is tightened by using two pairs of pliers in the manner shown in the photograph.

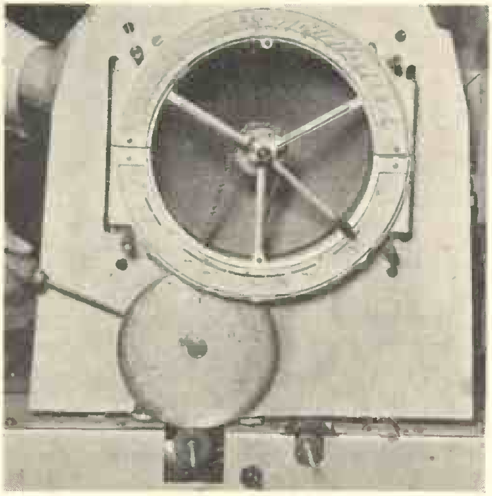


Fig. 14.—ANOTHER POSSIBLE CAUSE OF SLIPPING DRIVE.

The driving washers may be out of alignment with the driven disc. This can be remedied by loosening the two grub screws on the driving sprocket and allowing the disc to take up its correct position on the gang spindle.

then the component must have a break in the windings.

NOTES ON THE R.S.3 RECEIVER

Figs. 1 to 23 illustrate the various operations in the servicing of this type of receiver.

This receiver consists of two stages of screened grid amplification, leaky grid rectification, followed by power pentode output stage. The H.F. stages are transformer coupled (tuned), and the detector is coupled to the output valve by means of a 5–1 ratio L.F. transformer. The output from the pentode is fed to the moving coil loud speaker through a step-down output transformer. Full-wave rectification is used, the rectifier being a Mullard D.W.3. The loud speaker field winding is employed as part of the smoothing circuit. Wave-change and pick-up switching is carried out automatically by means of special switching arrangement.

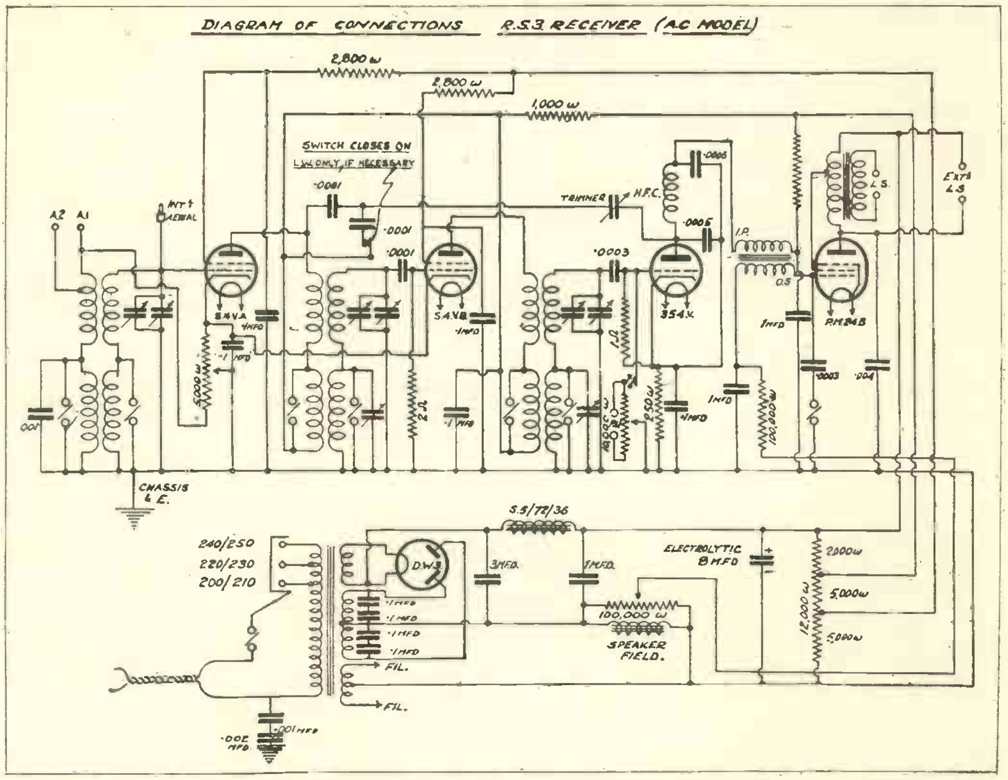


Fig. 14A.—THEORETICAL DIAGRAM OF R.S.3 RECEIVER (A.C. MODEL).

Constants of Receiver under Working Conditions

Voltage across electrolytic condenser, minimum 228.

Pentode Grid-bias .	25–35 volts.
S.G. Valve Anodes .	160–180 volts.
Screening Grids .	80–90 volts.
Detector . .	100–120 volts.
Pentode Anode .	215 volts minimum.
Detector Bias when Pick-up in use .	– 1·5 to – 2 volts.
Total consumption of Receiver from Mains . .	260 milliamperes A.C. (approx.).

D.C. Resistances of Coils, etc.

The following notes are for guidance in checking connections, switches, etc.

Aerial Coils

The aerial coil consists of a primary of 14 turns of medium wave and 30½ turns of

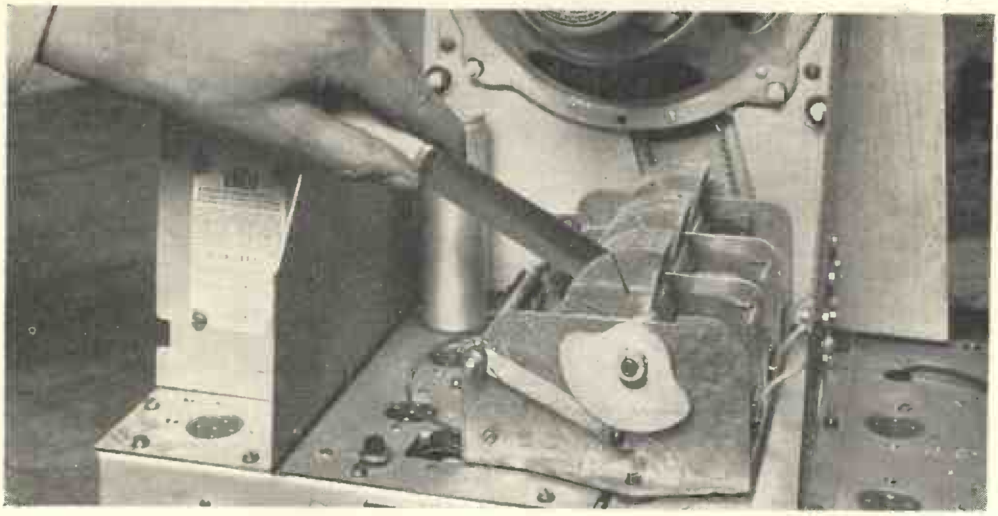


Fig. 15.—BENDING THE SPLIT END CONDENSER VANES WITH A TABLE KNIFE.

Bent vanes may be a cause of shorting, which usually occurs on the slotted vanes level with the slots. This should be cleared by bending the vanes as little as possible, otherwise it will be necessary to restep the receiver.

Fig. 16.—HOW TO ADJUST THE MEDIUM WAVE TRIMMERS TO OBTAIN CORRECT GAUGING.

Choose a weak station when the volume control is at maximum. Now close slightly the front and rear trimmers and rotate the centre trimmer for maximum volume. The same process should be carried out with the front and rear trimmers. If one of the latter is all out it will be necessary to close the centre trimmer slightly and restep. If it is necessary to close either the front or rear trimmers hard up for maximum volume it will be necessary to open the centre trimmer slightly and restep. To open the scale, close the trimmers. To close the scale, open the trimmers.

long wave, the long wave being switched out for medium wave reception. Resistances of the coils are as follows :—

Aerial coil primary—

Medium waves . .	4 ohms.
Long waves . .	13–14 ohms.

Aerial coil secondary—
- Medium waves . . 4 ohms.
- Long waves . . 19 ohms.

H.F. Transformers, etc.

The H.F. transformers are similar to the aerial coil except that the primaries are wound on small paxolin tubes fixed inside the secondaries. Resistances are as follows:—

H.F. Transformer Primary—
- Short waves . . 5 ohms.
- Long waves . . 13 ohms.

Intervalve Transformer—
- Primary . . . 750 ohms.
- Secondary . . . 10,000 ohms.

Potential divider. This is in three sections, consisting of two 5,000 ohm sections and one 2,000 ohm section.

Gramophone Bias Resistance . . . . 250 ohms.
Loud-speaker Field . . 2,040–2,060 ohms.

Voltage dropped across L.S. Field Winding . 120–140 volts.

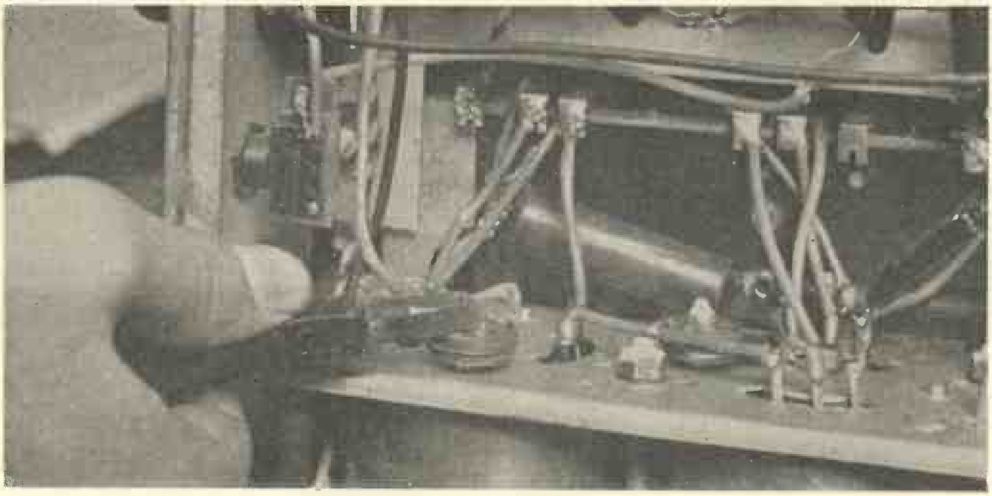


Fig. 17.—How to Adjust the Long Wave Trimmers.

On long waves an additional pair of trimmers are brought into operation. These are connected across the long wave sections of the H.F. transformer secondary and are adjusted by screwing or unscrewing the 6 B.A. nut over the washers. If the long wave calibration is uniformly out, some correction may be made by moving the scales together at one of the " gram " positions.

H.F. Transformer Secondary—
- Short Waves . . 4 ohms.
- Long waves . . 19 ohms.

(The two H.F. transformers are identical.)

Mains Transformer—
- Common tap to 250-volt tap . . . . 40 ohms.
- Common tap to 220–230 volt tap . . . 36 ohms.
- Common tap to 200–210-volt tap . . 32 ohms.

Output Transformer—
- Primary . . . 800 ohms.
- Tapping . . . 170 ohms.

H.T. Smoothing Choke . 500 ohms.
H.F. Choke . . . 130–140 ohms.

Current passing through Loud-speaker Field Winding . . . 50 milliamperes.
Pentode Plate Current—over 17 milliamps.
Pentode Auxiliary Grid Current—under 10 milliamps.

Notes on the Wave Change Switch

On all later models brass strips are screwed to the gang to form a bearing for the switch spindle. If these brass strips are not present the switch may give trouble after a short period of service. Rotating the gang in an anti-clockwise direction viewed from the front, the switch action is as follows:—

All-in: Gramophone contact making, all other contacts open, $\frac{3}{4}$, $\frac{1}{2}$ and $\frac{1}{4}$; medium wave contacts making, all other contacts open.

All-out: Gramophone contact making. H.T. making. The "gram" switch should contact at the actual minimum and maximum position of the gang condenser. The H.T. switch should make on long waves only. As will be seen from the circuit diagram this effectively puts the ·001 condenser in shunt with the first H.F. Transformer primary and causes the small pre-set condenser (marked as Trimmer) to become practically inoperative.

The Circuit

As will be seen from the theoretical diagram, this is a straightforward three-valve circuit, employing one stage of screened-grid H.F. amplification coupled to the detector valve by means of a tuned H.F. transformer. The detector works on the leaky grid principle, and is coupled to the output pentode through a low-frequency transformer having a ratio of 5 in 1. The loud speaker is specially wound to match the pentode, and is wired directly in the plate circuit of this valve. A feature of interest is the unusual aerial circuit employed. As will be seen from Fig. 23A, the S.W. primary is split, and the minimum capacity of the aerial series (volume control) condenser is balanced by a small pre-set condenser, so that no signal can get through when the volume control is at zero.

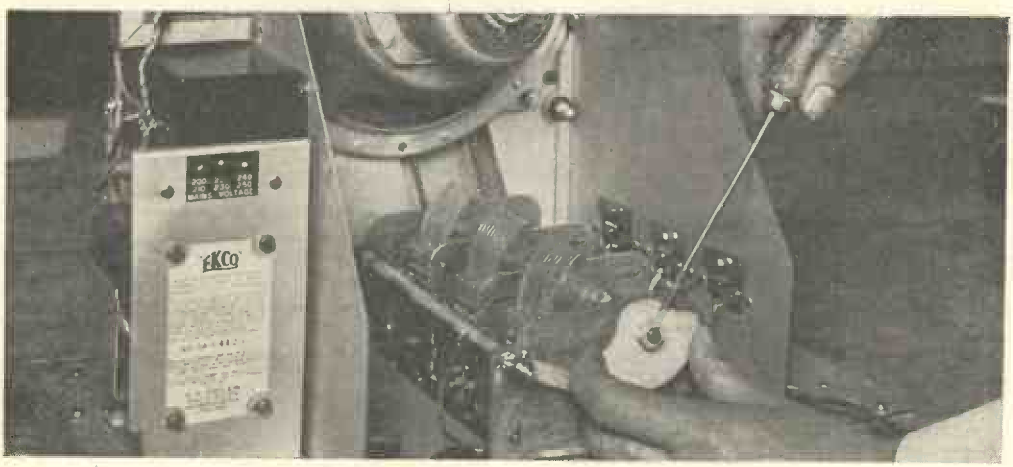


Fig. 18.—How to Set the Cam.

First release the cam from the condenser shaft by loosening the grub screws. Then calibrate in the usual way. Now fix the pointer and scale, next move the pointer to the centre of the right-hand gramophone position and reset the cam with the hand until a click is heard, then tighten both grub screws.

The contacts on the switch commencing at the rear are as follows :—

(1) Aerial primary tap.
(2) Aerial secondary tap.
(3) " H.T." contact.
(4) First H.F. primary tap.
(5) First H.F. secondary tap.
(6) Second H.F. primary tap.
(7) Second H.F. secondary tap.
(8) Gramophone.

THE R.S.2, A.C. RECEIVER

Many points regarding the servicing of this receiver are similar to those described for the R.S.3. Servicing points of the R.S.2 type are illustrated in Figs. 24 to 27.

Constants of Receiver under Working Conditions

Plate Potentials—

Loud speaker positive terminal to chassis (earth) .	140 volts.
Detector plate to chassis .	95 volts.
Screened-grid valve Plate to chassis . . .	140 volts.
Ditto, Screen to chassis .	95 volts.

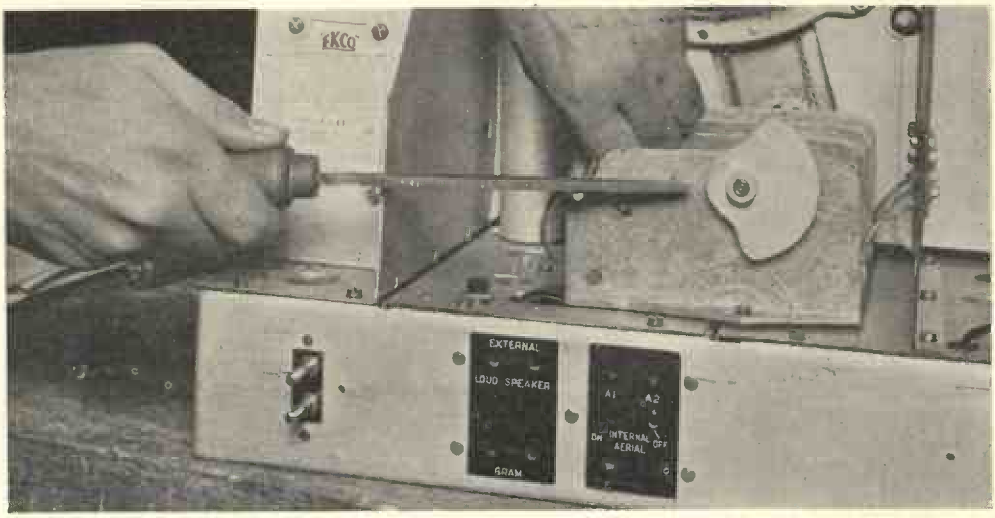


Fig. 19.—FILING A NEW FLAT ON THE SWITCH SPINDLE.

This may be necessary when the gramophone positions are not exactly 180 degrees apart. If bad contact is experienced it will be necessary to loosen off the cam arm fixing screw and rotate the wave change spindle until all the contacts can be bent conveniently to a correct position.

Fig. 20.—TESTING 0·1 CONDENSERS ON H.F. PANEL.

The simplest way to make sure whether a condenser is faulty is to try another condenser in parallel with each in turn.

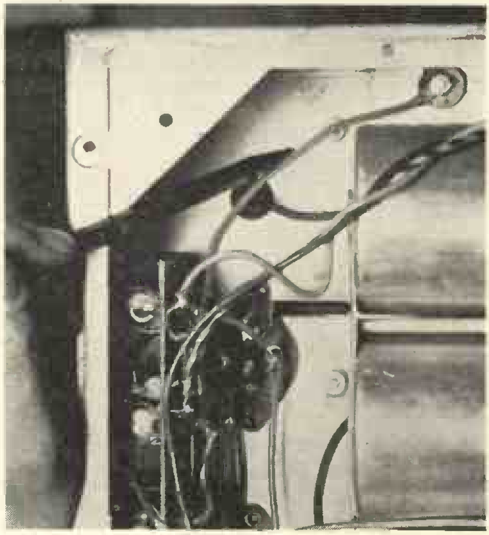


Fig. 21.—THE EARTH CONNECTION ON THE H.F. PANEL.

This is accomplished by taking a wire direct to the main chassis in addition to wire running to the rivet head.

Pentode bias, measured between H.T. choke tap and chassis . . . 12 volts.

H.F. bias across 600 ohms resistance . . . 0·6 volt.

L.T. across valve legs . 4 volt.

Note.—All the above voltages may vary by approximately 10 per cent.

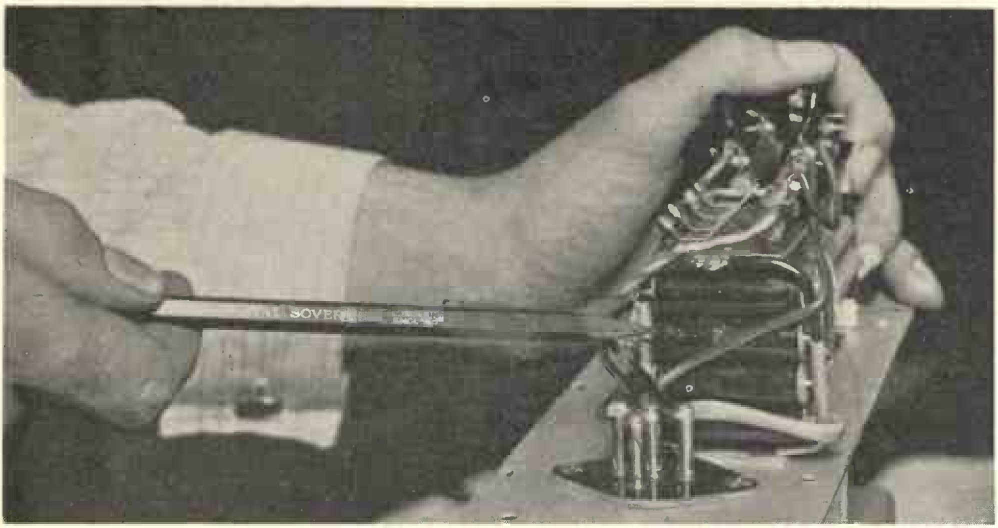


Fig. 22.—The Buffer Condensers across Transformer Secondary on Power Pack.

These condensers are fitted to cure tuned-in hum and are inserted across the H.T. secondary of the power transformer and from the mains to earth ; two 0·01 condensers in series are fitted across each half of the secondary winding and two 0·002 condensers in series from mains to earth.

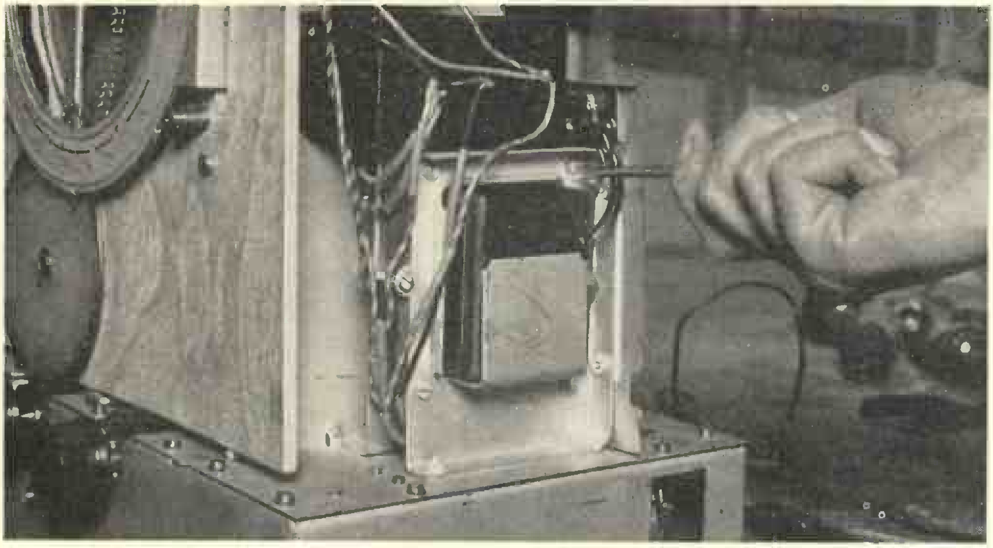


Fig. 23.—How to Cure Mechanical Buzz in the Mains Transformer.

This may be overcome by tightening the clamping bolts of the power transformer, beginning at the bolt adjacent to the mains adjustment panel. Should loud speaker resonance be present the faults to look for are : (1) resonance of grille ; (2) resonance of scales ; (3) dirt in gap ; (4) centring out of adjustment ; (5) damaged cone ; (6) solder on coil or coil leads ; (7) loose adhesive on coil ; (8) resonance of scale mounting.

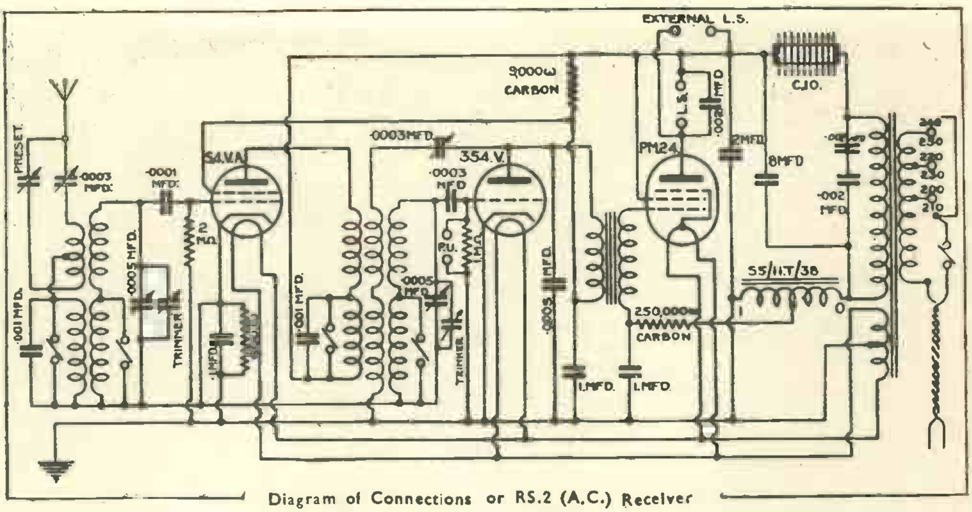


Fig. 23A.—THEORETICAL DIAGRAM OF R.S.2 (A.C.) EKCO RECEIVER.

This is a straightforward three-valve circuit, employing one stage of screened-grid H.F. amplification, coupled to the detector valve by means of a tuned H.F. transformer. Note the unusual aerial circuit employed.

THE R.S.2, D.C. RECEIVER

The Circuit

As will be seen from the theoretical diagram in Fig. 23B, this is a straightforward three-valve circuit, consisting of one stage of screened-grid H.F. amplification, coupled to the detector valve by means of a tuned H.F. transformer. The detector valve works on the leaky grid principle, and is coupled to the output pentode by means of an L.F. transformer having a ratio of 5 in 1.

The loud speaker is specially wound for use with a pentode valve, and is wired directly in the plate circuit of the output valve.

The special aerial volume control

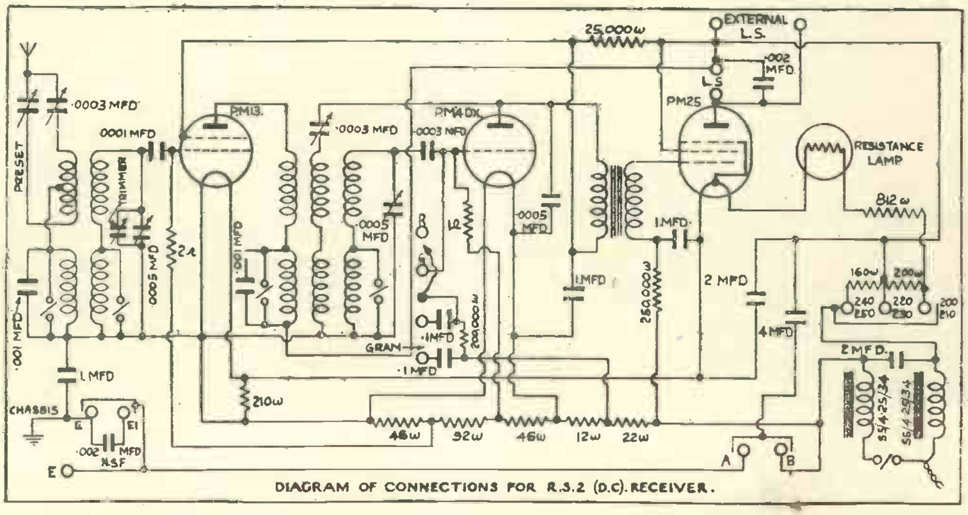


Fig. 23B.—THEORETICAL DIAGRAM OF R.S.2 (D.C.) RECEIVER.

Note the special resistance lamp incorporated to guard against mains variation.

Fig. 24.—Removing the R.S.2 Receiver from the Cabinet.

After removing the four cheese-head screws from the edges underneath the cabinet, remove the screws which hold the wooden back in position.

Fig. 25.—Removing Receiver from Cabinet. Second Stage.

The two screws at the top of the baffle board upon which the loud speaker is mounted should next be removed. Two further screws still hold the cabinet in position, and they are situated at the bottom of the baffle board near the two brackets.

Fig. 26.—Removing Receiver from Cabinet. Third Stage.

This shows the removal of lower screw from loud speaker baffle. The right-hand screw can be reached by means of a long screwdriver inserted between the mains transformer and the bottom of the rectifier. The remainder of the operations are the same as for the R.S.3 receiver.

arrangement incorporated has already been referred to in the description of the R.S.2, A.C., and therefore no further mention of it is needed.

Directly heated valves are employed, and a special "Resistance lamp," type 1904 (Philips), is incorporated to guard against mains variation, with its consequent damage to the filaments of the valves. This "Resistance lamp" will take care of a fluctuation in the mains of 20 volts either way.

Aerial Volume Control

If it is impossible to obtain a true zero on the aerial volume control, then the base of the receiver should be removed, and the pre-set condenser fixing collar loosened. The receiver should then be tuned to a powerful signal, and the small black knob controlling the pre-set condenser turned slightly to left or right (with the aerial series condenser set at zero) until the local station disappears. The fixing collar should then be tightened down to lock the condenser in this position.

Constants

Screened-grid Valve Plate .	170 volts.
Ditto, Screened Grid .	65 volts.
Ditto, Grid Bias . .	− 1 volt.
Detector Plate . . .	65 volts.
Ditto, Bias . . .	+ 1 volt.
L.S. Positive Terminal. .	165 volts.
Pentode Plate . . .	130 volts.
Ditto, Bias . . .	− 12 volts.

All voltages to be measured between that side of ballast lampholder which is connected to Pentode Filament and the points shown above.

Resistances, etc.

Mains Resistance, 360 ohms, tapped at 160 ohms.

Filament Resistance, 812 ohms.

Filament Shunts and Bias Resistances. Commencing at one end of resistance former, 46, 92, 46, 12, 22 and 250 ohms.

Filament Voltages

Pentode (P.M.25 D.C.).	3·5 to 4·5 volts.
Detector (P.M.4 D.X.).	3·25 to 4·5 volts.
S.G. (P.M.13 D.C.) .	3·5 to 4·5 volts.

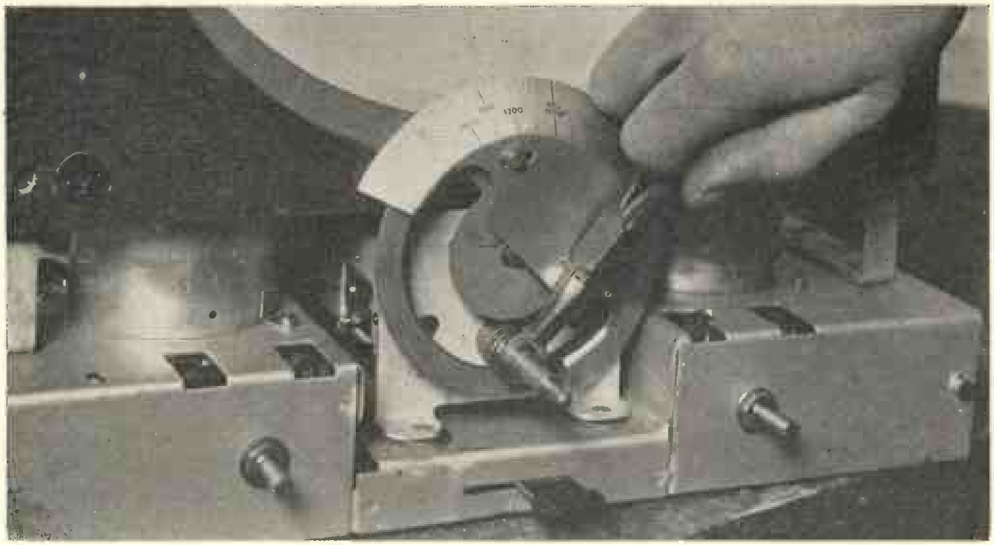


Fig. 27.—Removing Horseshoe Washer on Spindle of Twin Gang Condenser.

If trouble is experienced with slipping drive on the ganged condenser the small horseshoe washer should be straightened and removed. The spring can then be taken off the spindle and slightly stretched. It should then be replaced and the washer inserted to hold it in position, the ends being bent over as before.

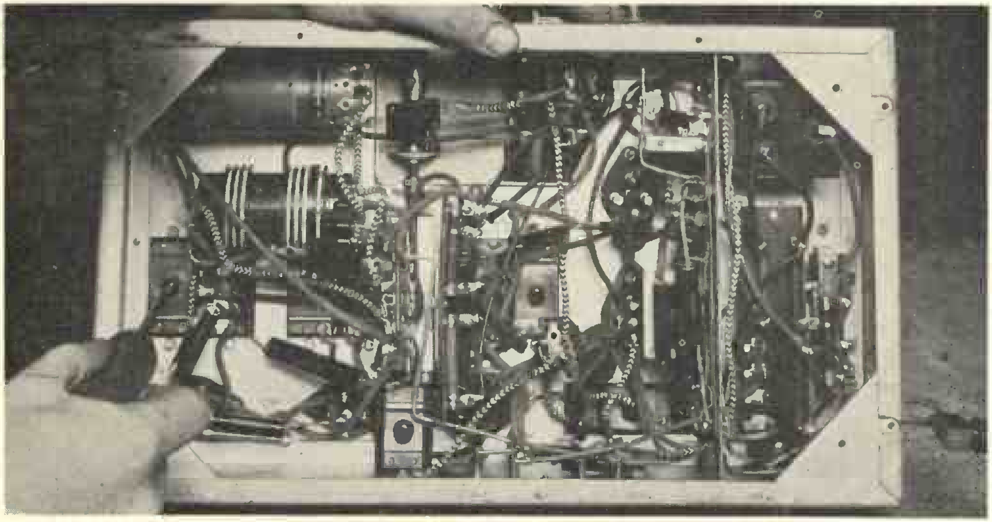


Fig. 28.—SETTING THE PRE-SET CONDENSER OF THE S.H.25 RECEIVER.
This photograph also shows the general appearance of the base.

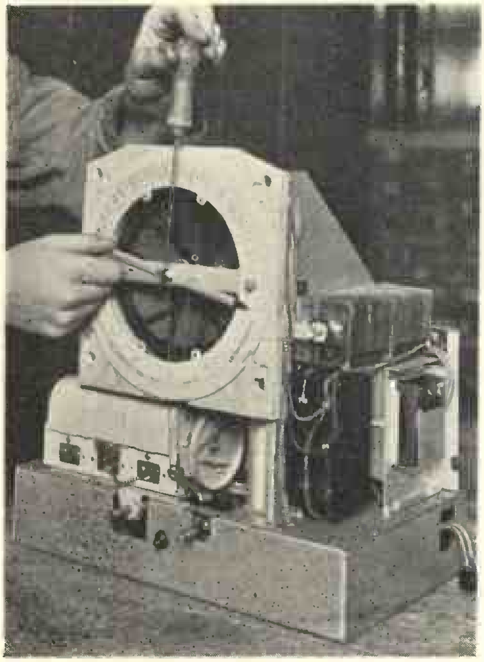


Fig. 29.—SHOWING THE METHOD OF TIGHTENING THE POINTER INDICATOR OF THE S.H.25 RECEIVER.

It will be seen that two screws are provided for this purpose. The pointer is held firm while these screws are tightened up.

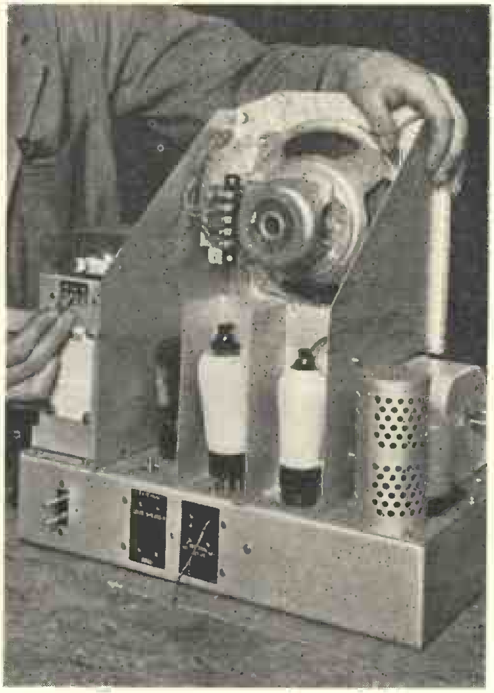


Fig. 30.—SETTING THE MAINS CONTACT SCREW TO UNIT SUPPLY VOLTAGE.

This is the method employed in all Ekco receivers. Three variations in voltage are provided, *i.e.*, 200–210, 220–230, and 240–250, and the screw is inserted in whichever voltage is required.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION II. STATIC ELECTRICITY

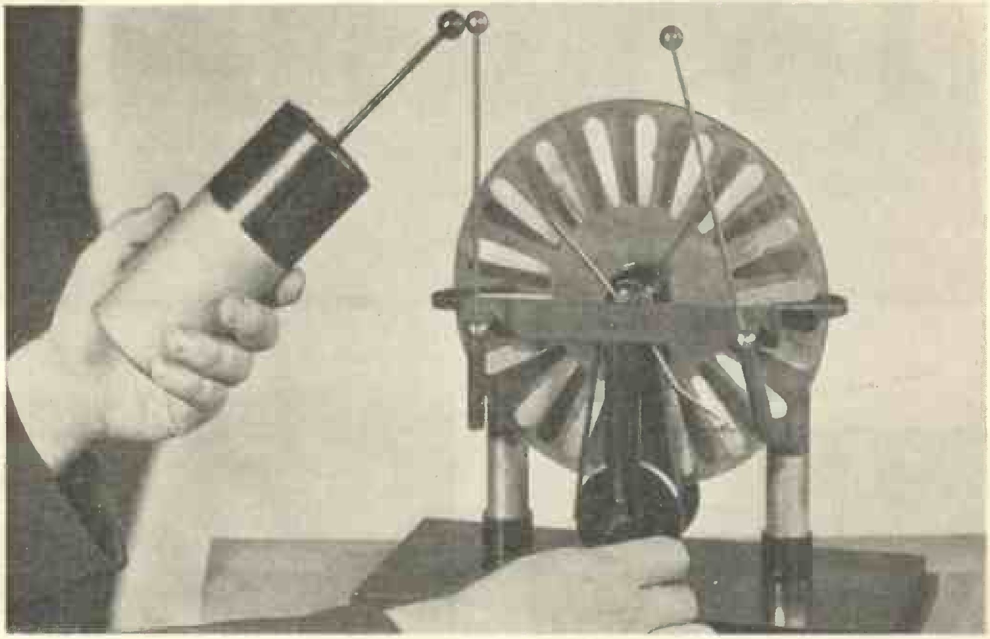


Fig. 1.—A Wimshurst Machine and Leyden Jar.

This machine is used for producing high potential charges of electricity. It consists of two glass plates with strips of tinfoil pasted radially on each plate. When the handle is turned the plates rotate in opposite directions, and small wire brushes collect the charges of positive and negative electricity from either plate. In the picture a Leyden Jar is being charged. This was the earliest form of condenser and consists of a glass jar with a sheet of tinfoil pasted round the lower half of the outside of the jar and another sheet pasted on the inside of the jar.

IN the ancient times somebody stumbled upon the fact that a piece of *amber* (a yellow transparent resin found on the seashore) if rubbed with a piece of cloth will attract to itself small light bodies such as small pieces of pith. The ancient Greeks called amber *electron* and this name has been responsible for the description of the attractive properties of amber as *electrification.*

Electrification was supposed to be due to some mysterious "fluid" residing in amber and released by friction. This mysterious "fluid" was called *electricity.*

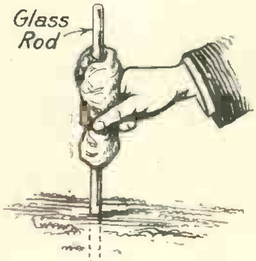


Fig. 2.—A Glass Rod can be Electrified by rubbing it with a Soft Handkerchief.

In this case the glass rod is electrified negatively.

As soon as the attractive property of amber subjected to friction became known further experiments were carried out with a number of other substances and it has been found that glass, sulphur, pitch and some similar substances, when rubbed with cloth, fur or silk, behaved in precisely the same manner as amber.

Positive and Negative Electricity

It has been further discovered that not only the rubbed substances became electrified but that the rubbing substance itself was also subject to electrification, but it appeared that in this latter case the electricity was of a different kind, and for this reason it has been decided that there must be two kinds of "fluids," *i.e.*, two kinds of electricity, residing in each body and separated from each other by friction.

As you will see from further studies this assumption proved to be very near the truth, although electricity is not a fluid.

In order to distinguish between the two kinds of electricity one of them was called *positive electricity* and the other *negative electricity*. The words positive and negative have no special meaning, they merely indicate that the two things are different from each other.

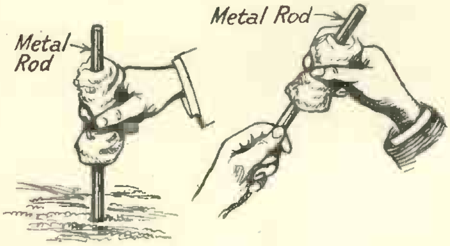


Fig. 3.—A METAL ROD CANNOT BE ELECTRIFIED BY RUBBING BECAUSE THE ELECTRICITY LEAKS AWAY.

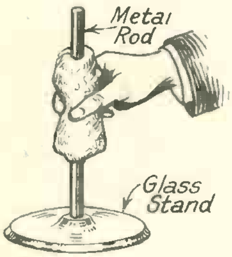


Fig. 4.—A METAL ROD MOUNTED ON A GLASS STAND CAN BE ELECTRIFIED BY RUBBING.

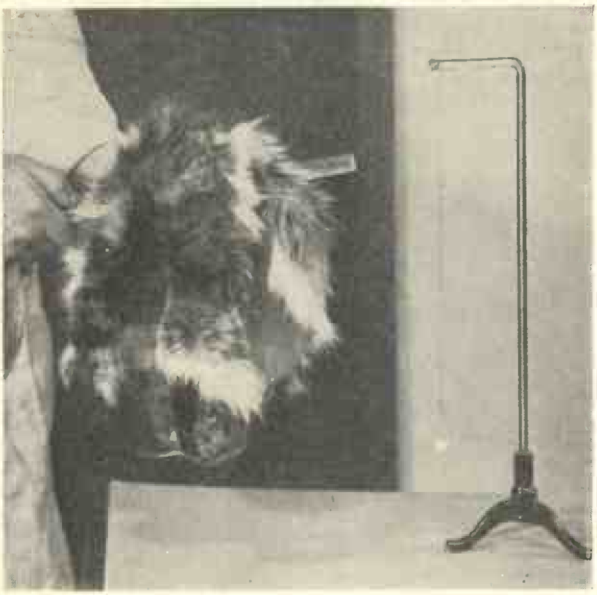


Fig. 5.—A GLASS ROD RUBBED WITH CAT'S SKIN BECOMES POSITIVELY CHARGED.

Notice the pith ball suspended from an insulated stand. See next figure.)

Why a Metal Rod is not usually Electrified by Rubbing.

During the early experiments it became obvious that not all substances can be electrified with the same ease as amber, glass or sulphur, and that *metal* rods held in one's hand could not be electrified at all. There seemed to be, in the case of metal, some leakage, as if electricity produced by friction were escaping somewhere.

How to Electrify a Metal Rod by Friction

It was subsequently found that while a glass rod fixed directly in the ground could be as easily electrified as when held in one's hand, a metal rod similarly placed still refused to be electrified. But when the same metal rod was fixed on a glass plate electrification took place.

Conductors and Insulators

This result made clear that if metals were to be electrified they had to be *isolated from the ground* by such a substance as glass and that the human body was not conducive to isolation. The substances which helped to isolate metals from the ground for electrification purposes were called isolators and later *insulators*. Metallic and a few other substances, which did not behave in the same way as the insula-

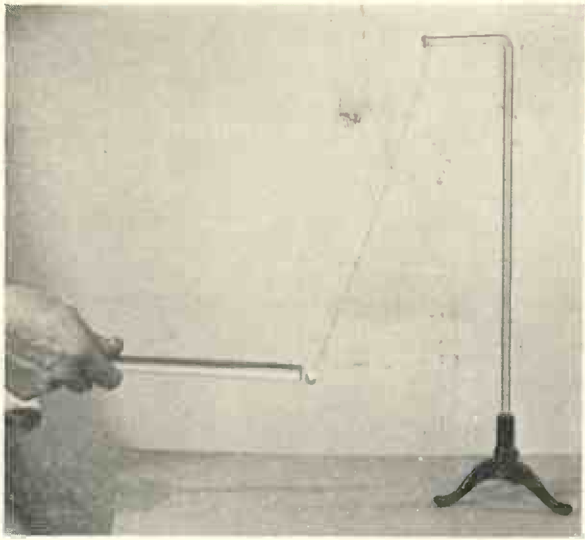


Fig. 6.—HERE WE SEE THE ELECTRIFIED GLASS ROD ATTRACTING THE PITH BALL.

tors and apparently helped electricity to escape into the ground (earth) or, in other words, conducted it to the ground, were called *conductors*.

There is a good deal of difference in the behaviour of conductors and insulators on electrification. An insulating substance when rubbed at one spot, will show the presence of electricity at that spot only, the other parts of the insulator failing to exhibit any signs of electrification. In the case of a conductor if one spot is electrified by friction the whole conductor becomes electrified, as if the electricity were spreading evenly all over its surface. For this reason it is sufficient to touch a conductor with an electrified body in order to electrify the whole of the conductor by *contact*. An insulator similarly treated will be electrified at the point of contact only. Both kinds of electricity can be thus communicated from one body to another.

Electric Attraction and Repulsion

Following the discovery of attraction by electrified amber, it has been found that when two bodies are electrified and the electrification on each is of the same kind they *repel* each other. If the electrification is of a different kind they *attract* each other. An electrified body will attract small unelectrified bodies, as is the case of electrified amber and small pieces of pith, and the reason for this phenomenon will become apparent shortly.

Two bodies of the same dimensions and shape if electrified with different kinds of electricity, one having positive electrification and the other having an equal negative electrification, when brought into *close contact* appear to lose all electrification, as if *the two kinds of electricity abolish each other.*

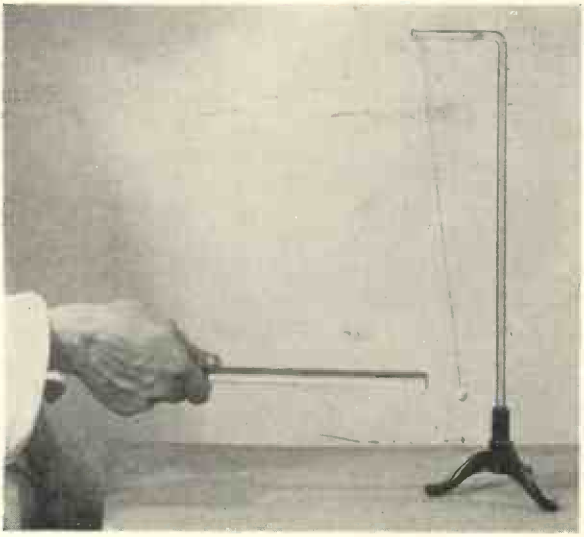


Fig. 7—LIKE CHARGES REPEL.

In the previous experiment the pith ball touched the glass rod and immediately became positively charged. It is now repelled by the electrified rod as can be seen above.

A simple Electrical Detector You can Make—The Electroscope

Owing to the repulsion of similarly electrified bodies it has been possible to produce an instrument which will detect the presence of electricity on an electrified body. This instrument is called an *electroscope* and it consists of a small metal rod carrying at one end a small metal disc and at the other end two very light metal leaves. The rod is threaded through a cork placed in the opening of a glass jar as shown in the accompanying illustration (Fig. 9).

When the metal disc at the top of the metal rod is brought into contact with an electrified body, electricity will pass from the electrified body to the disc, from the disc to the rod and from the rod to each leaf. As the two leaves are now electrified by contact with the same kind of electricity they are bound to repel each other, this repulsion showing that the electroscope became electrified on contact with an electrified body. Should the leaves fail to diverge it means that the body which the electroscope is touching is not electrified. Thus it is clear that an electroscope can be used as a detector of electrification.

The divergence of electroscope leaves also indicates the intensity of electrification of the body under investigation. The further the leaves are apart the greater the electrification of the body. Such an electroscope is easily made and will serve as an excellent detector of electrification produced by all sorts of means, means which are not so obvious as that of friction, and which are described further.

Fig. 8.—A Gold Leaf Electroscope.

This acts as a delicate detector of electrical charges. It consists of two pieces of gold leaf or bronze leaf mounted as shown inside a glass jar.

Electric Induction

Up to the present we have discussed two methods of electrification, viz., by friction and by direct contact. There is another method called *electrification at a distance*. That such electrification at a distance, *i.e.*, without friction or direct contact, exists can be easily checked with the help of the electroscope. If an electrified body is brought near a normal (unelectrified) body and the latter is touched with an electroscope it is found that the leaves diverge indicating that somehow the normal body became electrified (Figs. 10, 11 and 12). On investigation it is easily discovered that the "normal" body now possesses simultaneously two kinds of electrification in equal measure, positive electricity making its appearance at one end and negative electricity at the other end, the middle of the body being hardly electrified at all.

If the influencing electrified body carries, say, negative electricity, the normal body near which the electrified body is placed will show positive electricity at the near end and negative electricity at the far end (see illustration). It appears that one can easily assume that an unelectrified body normally carries the two kinds of electrification in equal measure which are so mixed as not to show any electrification at all. When an electrified body is brought near and is, say, electrified with negative electricity, the latter attracts to the near

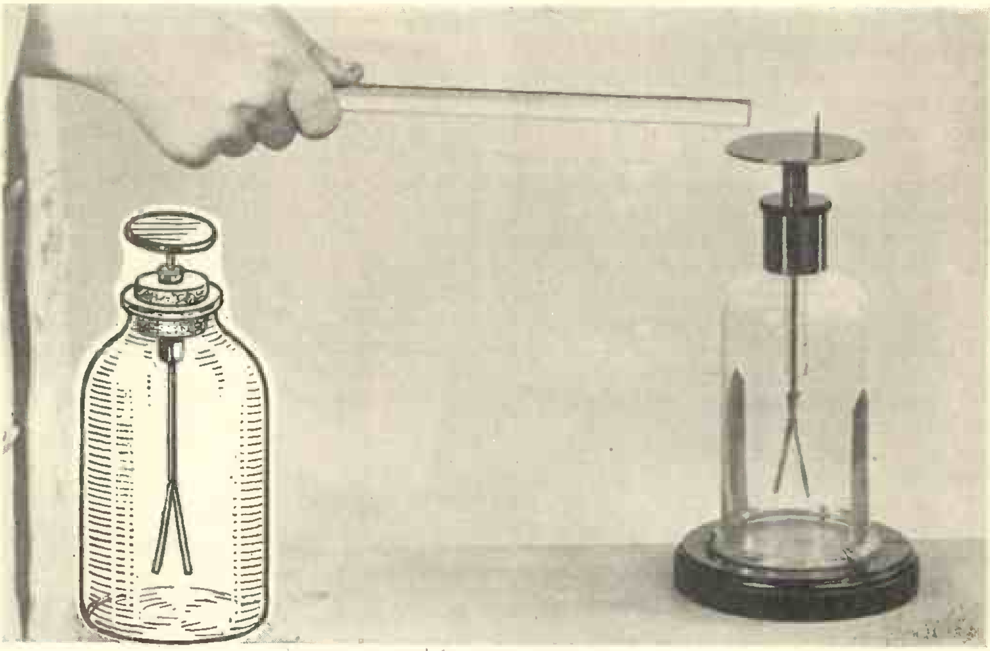


Fig. 9.—THE ELECTROSCOPE IN ACTION.

Notice that when the electrified rod is brought near the top of the electroscope the leaves fly apart.

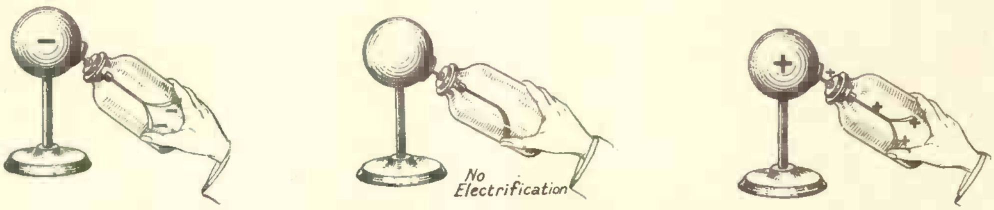
end the positive electricity in the normal body (this explains why electrified amber attracts small normal bodies) and at the same time repels the negative electricity in it. Why this should be so will become apparent from the article dealing with the nature of electrical phenomena.

Such electrification at a distance is called *electric induction*.

Some inquisitive person happened to touch with a piece of copper wire two metal spheres mounted on insulating stands of which one was electrified and the other normal. He found that there was a flow of electricity from the electrified sphere to the normal sphere and that the latter also became electrified. The electroscope proved this. Thus it was discovered that electricity will flow from one conductor to another provided there is a conducting path between them. Such a flow of electricity is called an *electric current*. We have already seen that this can be produced by several different methods.

The Electric Spark

In the case of two conductors highly electrified with opposite kinds of electricity and brought near each other, electricity escapes with some violence from one conductor to another and the result is a spark. But an isolated electrified body, in losing its electricity into the air, will take some time to lose all its electrification.



Figs. 10, 11 *and* 12.—THESE THREE PICTURES SHOW HOW THE ELECTROSCOPE BEHAVES WHEN BROUGHT NEAR NEGATIVE, NEUTRAL, AND POSITIVE CHARGES OF ELECTRICITY RESPECTIVELY.

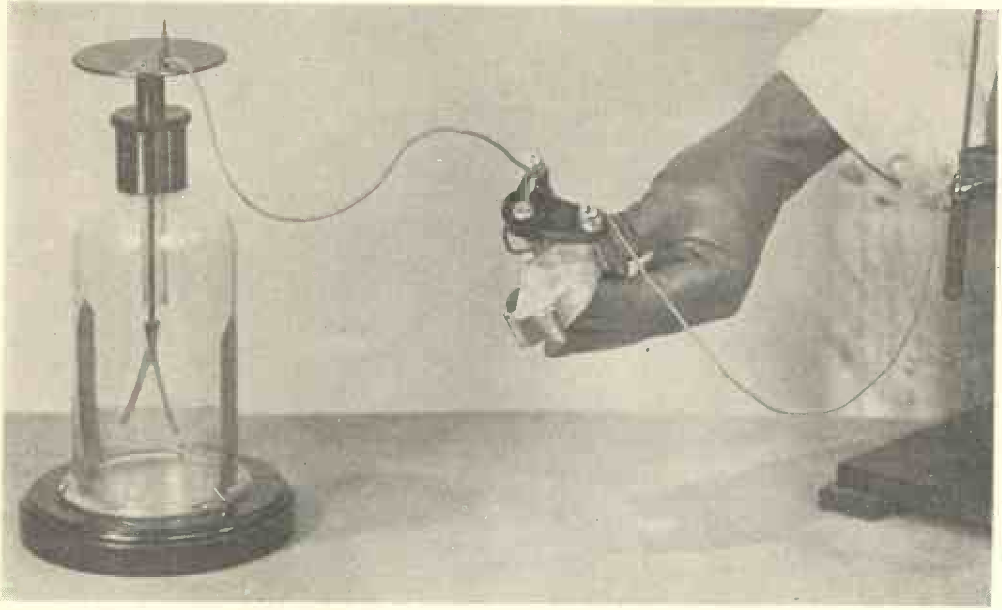


Fig. 13.—Demonstrating that an Electric Charge can pass across a Variable Condenser.
Note the position of the electroscope leaves.

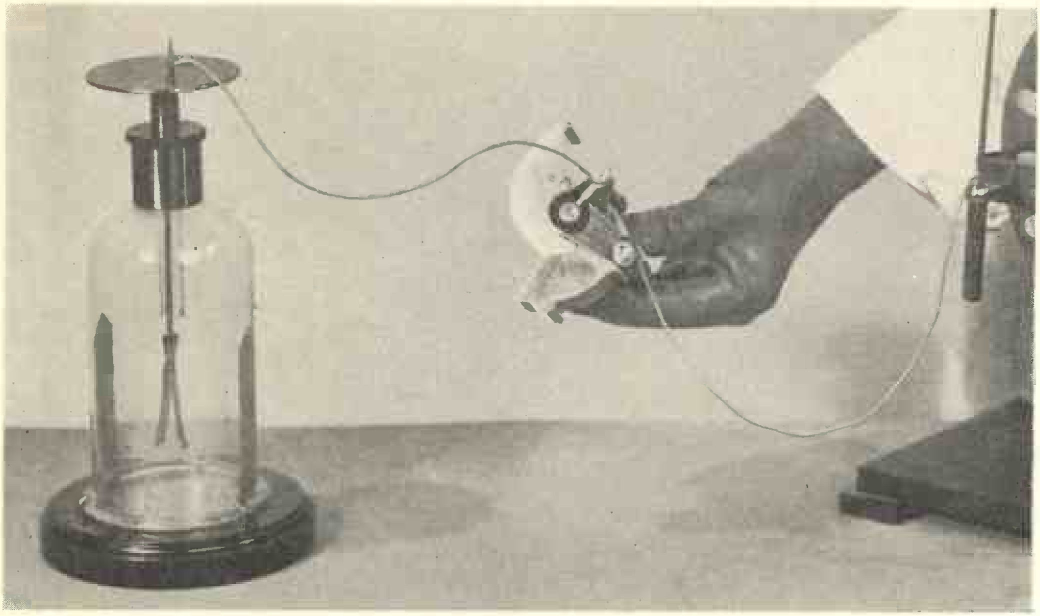


Fig. 14.—Effect of reducing the Capacity of the Condenser.

Note that in this case the electroscope leaves are closer together showing that opening the vanes of the condenser reduces the electrostatic induction between the fixed and movable vanes.

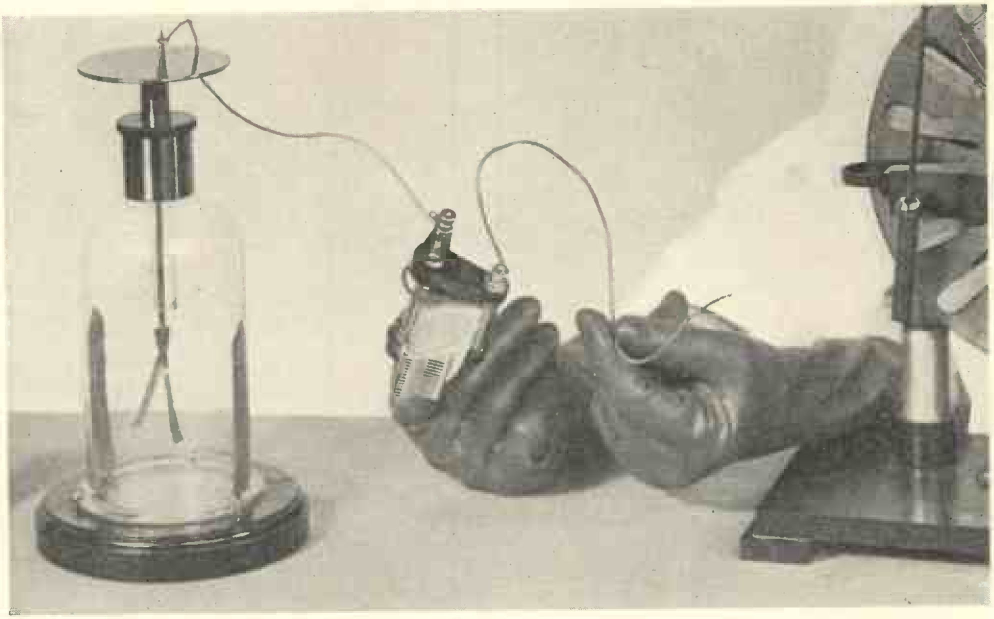


Fig. 15.—THE CONDENSER WILL RETAIN ITS CHARGE.

Note that though the condenser has been disconnected from the Wimshurst machine, the leaves of the electroscope are still open, showing that a small charge still remains in the condenser.

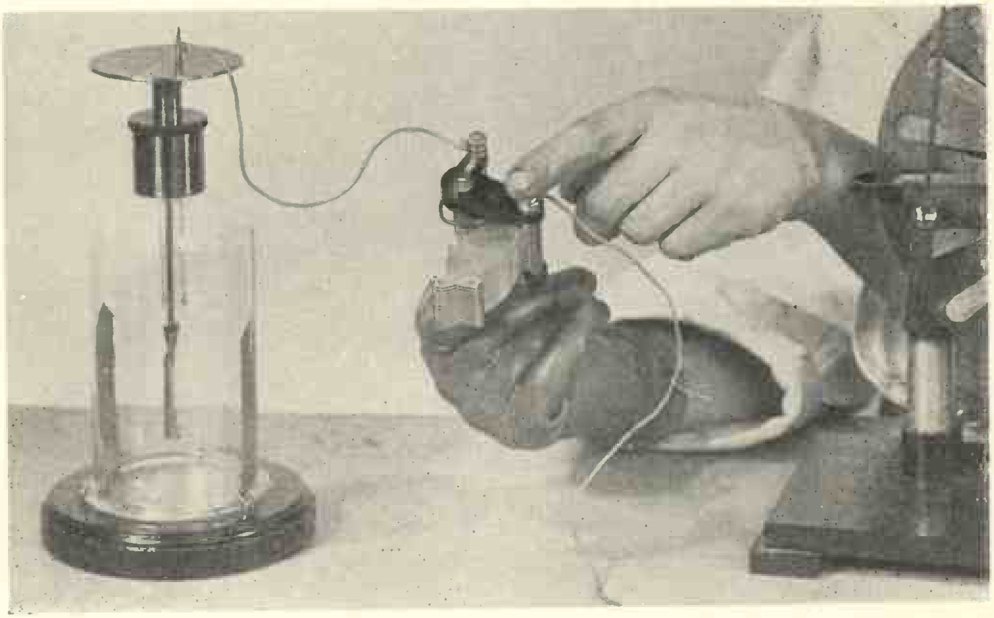


Fig. 16.—DISCHARGING THE CONDENSER TO EARTH.

By touching one terminal of the condenser the charge immediately escapes to earth as can be seen from the position of the electroscope leaves.

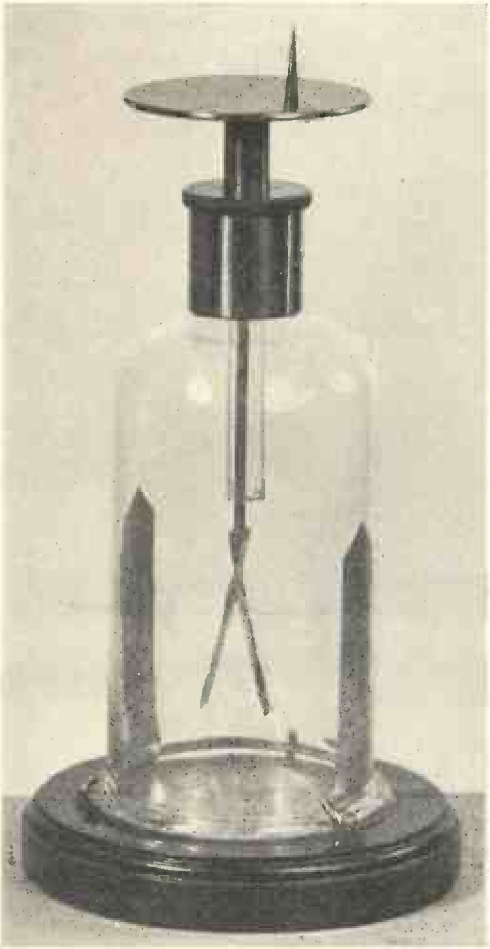


Fig. 17.—THE CHARGED ELECTROSCOPE.

This electroscope has been charged, and its electrified state is indicated by the position of the leaves.

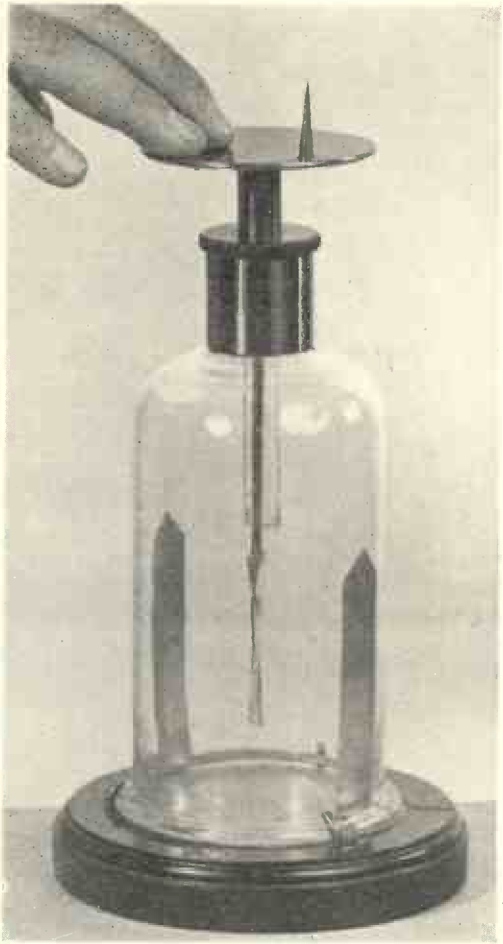


Fig. 18.—DISCHARGING THE ELECTROSCOPE.

When the metal plate is touched the charge flows to earth and the leaves fall together.

The Electric Wind

A very interesting phenomenon has been discovered in the case of an electrified conductor having a sharp point. It produces what is known as *electric wind*. A candle flame brought near such an electrified sharp point will

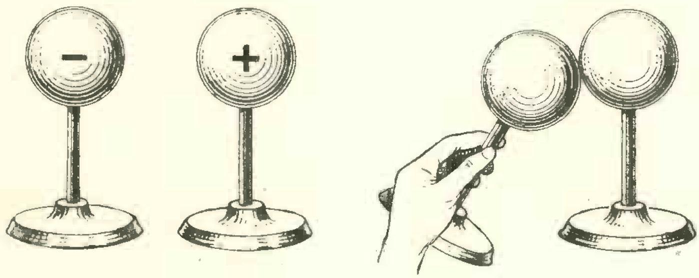


Fig. 19.—ILLUSTRATING HOW EQUAL POSITIVE AND NEGATIVE CHARGES NEUTRALISE EACH OTHER WHEN BROUGHT INTO CONTACT.

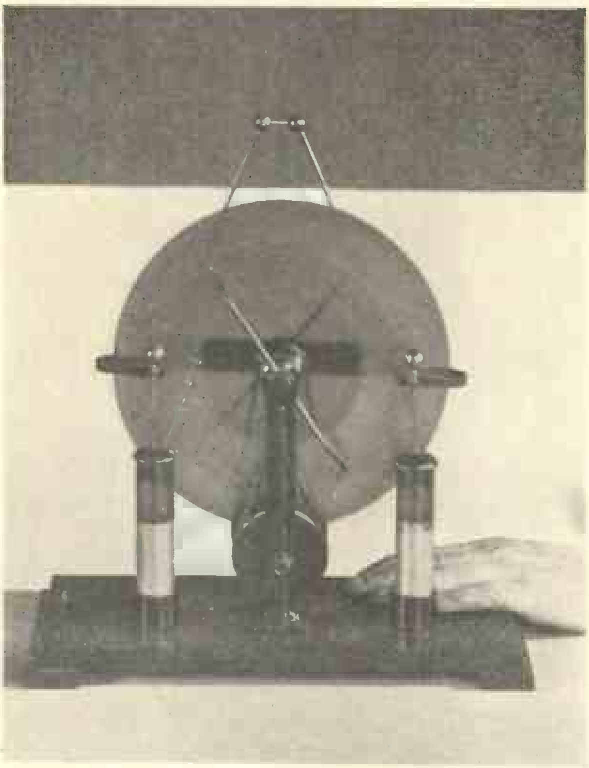


Fig. 20.—The Wimshurst Machine in Action.

Here we see the machine shown in Fig. 1 being rotated rapidly. Notice the continuous electric discharge passing between the terminal nobs at the top in the form of a stream of sparks.

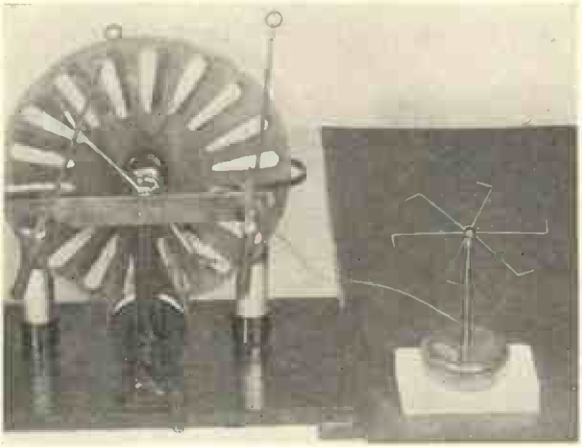


Fig. 21.—An Electric Mill Connected to the Wimshurst Machine.

be blown to one side (Fig. 23). A small mill mounted on top of an electrified conductor, as shown in the accompanying illustration (Fig. 21A), will rotate all the time while the conductor is electrified. In the latter case the escaping electricity from the sharp points pushes the mill round.

Static Electricity is produced in many different Ways

Electricity produced by friction has to be taken into consideration in everyday life. Thus you may have noticed that in factory shops lathes are

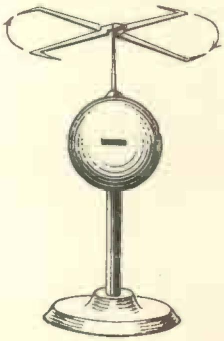


Fig. 21A.—Another Form of Electric Mill.

connected to earth either with the help of a chain or a stout wire. The reason for this is that the friction between the pulley and the transmission belt generates electrification which may give an unpleasant shock to the operator if the lathe is not connected to the ground and the only escape for electricity is through the operator's body.

Friction is not the only method of electrification. It is possible to electrify two bodies each with a different kind of electricity by merely striking violently one body with the other. The cause of electrification in this case is a mechanical blow.

A metal rod covered throughout its entire length with an insulating substance and subjected to violent mechanical vibration (oscillation) will become electrified.

If you take a linen-lined envelope, such as supplied by the post office for registered letters, and tear it violently you will find that each piece is electrified. A violent separation of two layers of mica will produce similar results.

By stroking a cat in the dark, combing your hair, crunching a piece of sugar, etc., you will be able to produce electrical phenomena accompanied by faint sparks.

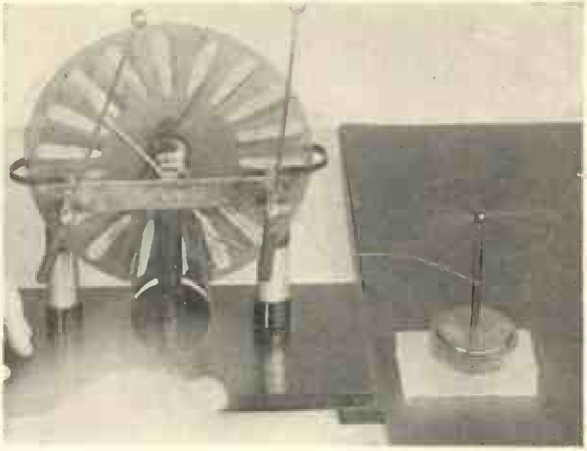


Fig. 22.—THE ELECTRIC MILL IN ACTION.

The plates of the Wimshurst machine are being rotated and the discharge from the points of the electric mill causes the latter to rotate rapidly

A melted substance on solidification becomes electrified. Combustion is also accompanied by electrification. Violent evaporation will produce the same result.

There is a large number of substances which become electrified when subjected to a mechanical pressure.

Many crystals, amongst them crystals of tourmaline, become electrified on heating.

Thus it is clear that any energetic mechanical action such as friction, percussion, vibration, violent separation and pressure will cause electrification. Similarly physical changes of state such as solidification, evaporation or expansion on heating, as well as the chemical changes taking place in combustion, may all be causes of electrification.

The reason for this phenomena will become quite clear when you make your acquaintance with the little " fellows " called *electrons*.

The Condenser

The condensers used in wireless work have been developed from the Leyden jars which were used by earlier experimenters for storing static electricity. The illustrations accompanying this article show some of the methods of producing static electricity and also how the Leyden jar is " charged " and discharged. They also show the electroscope and its application for detecting electrical charges and give a very clear view showing how a charge of static electricity can be applied to an ordinary variable condenser.

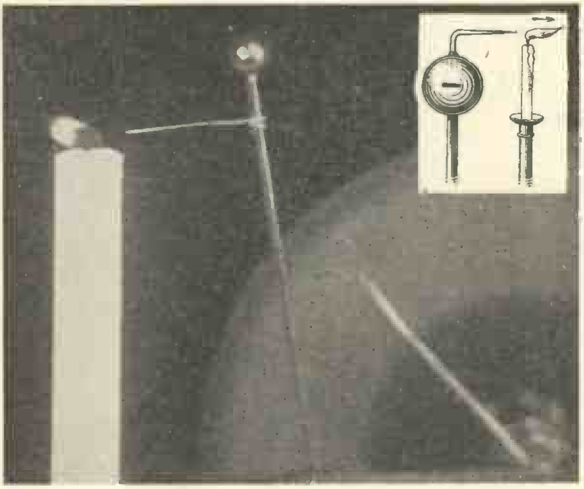


Fig. 23.—ANOTHER DEMONSTRATION OF AN ELECTRIC WIND.

A wire attached to one of the terminals of the Wimshurst machine produces a wind sufficient to deflect a candle flame.

Fig. 24.—ELECTRIFYING BROWN PAPER.

Brown paper can be electrified by friction as shown above.

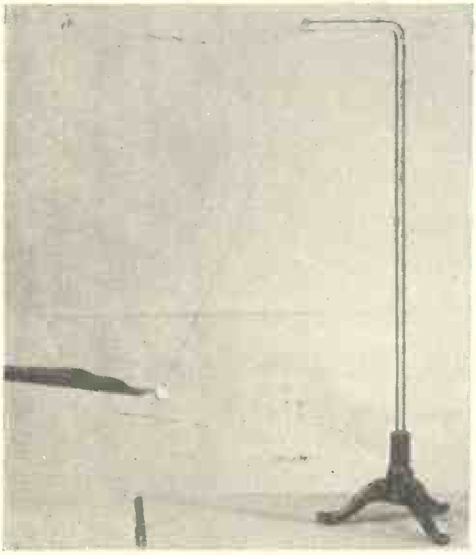


Fig. 25.—ELECTRIFIED PAPER ATTRACTING A PITH BALL.

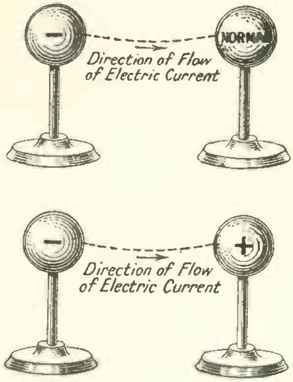


Fig. 26.—HOW ELECTRONS FLOW BETWEEN CHARGED BODIES.

Fig. 27.—A POSITIVE OR NEGATIVE CHARGE CONDUCTED TO A METAL BODY IS DISTRIBUTED EQUALLY OVER THE SURFACE.

Notice the pith balls being repelled from each end.

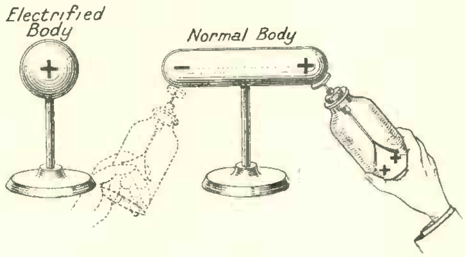


Fig. 28.—ILLUSTRATING ELECTRIFICATION BY INDUCTION.

In this case opposite ends of the conductor on which the charge is induced are at opposite potentials.

QUESTIONS AND ANSWERS

What are Electrons ?

Negative charges of electricity.

What Happens When a Glass Rod is Rubbed with (a) A Silk Handkerchief, (b) A Piece of Cat's Skin

(*a*) The rod becomes negatively electrified.

(*b*) The rod becomes positively electrified.

What do the Terms Negatively and Positively Electrified Mean ?

A body which is negatively electrified has had additional electrons imparted to it.

A body which is positively electrified has had some electrons taken away from it.

Why Cannot a Metal Rod be Easily Electrified by Friction ?

Because, owing to the fact that metal is a good conductor of electricity, the electric charge flows away to earth through the body of the person holding the rod.

Can a Metal Rod be Electrified by Friction?

Yes, providing the rod is insulated so that the charge cannot leak away.

What Other Way Could You Electrify an Insulated Metal Rod ?

By connecting the rod to the positive terminal of a high tension battery. This would give it a positive charge. Or by connecting it to the negative terminal of the battery. This would give the rod a negative charge.

State the Laws of Electric Attraction and Repulsion

(1) Two bodies electrified in the same way repel each other.

(2) Two bodies electrified in opposite directions, *i.e.*, positive and negative, attract each other.

(3) A body electrified either positively or negatively will attract a non-electrified body.

What is an Electroscope ?

It consists essentially of two pieces of gold leaf fixed to one end of a metal rod ; the latter for convenience being mounted in a glass jar.

What is the Use of an Electroscope ?

It provides an extremely sensitive method of detecting the presence of small electric charges. A small positive or negative charge will cause the leaves of the electroscope to fly apart.

What is Electric Induction ?

When an electrified object is brought near to one which is not electrified the latter becomes electrified as illustrated in Fig. 28.

How Does this Induced Electrification Differ from Electrification by Contact ?

(*a*) As soon as the original charged body is removed the induced charge on the second body disappears. In the case of electrification by direct contact the body remains charged after the original electrified body has been withdrawn.

What is the Chief Function of an Electrical Condenser ?

To store a small charge of electricity which can be given out again when required.

Is this the Action of Condensers Used in Wireless Receivers ?

Yes. In an alternating current circuit or a high frequency circuit the condenser stores a small charge of electricity during one half-cycle and gives it out during the second half-cycle. A condenser stores electrical energy in the same way that a spiral spring stores mechanical energy. Just as a spring and weight can be tuned to vibrate mechanically so an electrical circuit containing a condenser and a coil can be tuned to an electrical vibration.

METHODS OF VOLUME CONTROL

By HARLEY CARTER

CONTROL of volume is exercised in modern receivers for one or other of two reasons: first, to avoid overloading of some particular valve stage with consequent distortion, and second, to permit the loudness of the programme to be adjusted to suit the taste of the listener.

In either case, the methods available fall into two main divisions—control by limiting the signal input to the receiver, and control by adjustment of the degree of amplification in one or other of the amplifying stages.

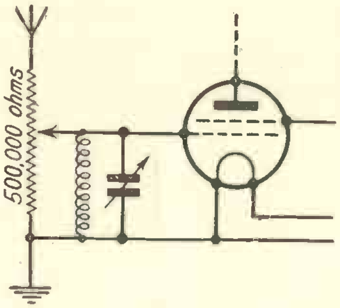


Fig. 1.—VOLUME CONTROL BY POTENTIOMETER IN AERIAL CIRCUIT.

CONTROL BY LIMITING INPUT

The signal voltage passed to the grid of the first valve (usually a high frequency amplifier) can be varied by connecting a potential divider between the aerial and earth and tapping off a portion of the signal for use in the set. The potential divider may be an ordinary resistance potentiometer having a total value of 500,000 ohms and connected as in Fig. 1. This method is simple and inexpensive, and is effective not only for varying the volume level, but also for reducing the input to the high frequency valve to a value which the valve can handle without distortion.

A Disadvantage of Potentiometer Control

Its chief disadvantage is that as the potentiometer is adjusted the tuning of the receiver is slightly upset so that a certain amount of re-adjustment of the aerial tuning condenser is necessary. Potentiometer control of the input is therefore unsuitable for receivers using "ganged" tuning circuits.

A further disadvantage is that when the programme level is reduced, the amount of incidental "background" noise is not correspondingly decreased, so that the "background" sounds more noisy in comparison.

Using a Differential Condenser

As an alternative to a resistance potentiometer, a differential condenser of ·00005 mF. may be employed as a "capacity potentiometer." If connected as shown in Fig. 2, the total added capacity in shunt with the tuning circuit is practically constant for all settings of the differential condenser, and smooth volume control is obtained. Here, too, however, the tuning of the circuit may be slightly upset when the differential condenser is adjusted, but this effect can be minimised by connecting a small condenser in series with the differential condenser as indicated in Fig. 3. The capacity of this condenser should be of the order of ·00005 mF., and may conveniently be a semi-variable or "pre-set" condenser. It should be set at a value near its minimum capacity, and the best adjustment found by trial. With care in adjustment this arrangement can be operated quite successfully even in circuits employing ganged tuning condensers.

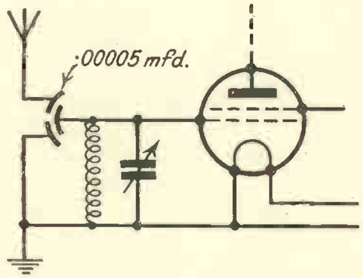


Fig. 2.—VOLUME CONTROL BY DIFFERENTIAL CONDENSER IN AERIAL CIRCUIT.

CONTROL BY LIMITING AMPLIFICATION

This form of control may be applied to high frequency stages, to the detector, or to any of the low frequency stages of a receiver. In some sets it may be convenient to fit volume controls to more than one stage in the interest of good quality reproduction. For example, high frequency control may be used for both programme control and for avoiding rectification in the radio-frequency stage, while an additional control may be necessary to avoid overloading a pentode output valve when strong signals are being received.

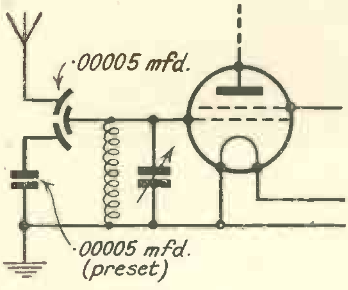


Fig. 3.—Improved Circuit for Volume Control by Differential Condenser in Aerial Circuit.

Control by limiting High Frequency Amplification

One of the simplest methods of controlling volume on the high frequency side of a battery-operated receiver is by fitting a rheostat in the filament circuit of the high frequency valve. By dimming the filament the effective sensitivity of the valve is reduced, with a corresponding decrease of stage gain. The connections are shown in Fig. 4. For the average 2-volt screened grid valve a resistance having a total value of 30 to 40 ohms is required.

Although simple and effective, and inexpensive to instal, this method of control is somewhat "fierce," that is to say, it is impossible to obtain that smooth gradation of volume from maximum to minimum which is obtainable with other methods of control.

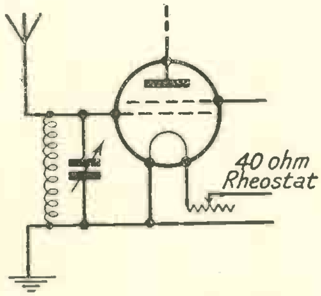


Fig. 4.—Volume Control by Rheostat in Filament Circuit of H.F. Valve.

Varying Voltage to Screen of Screened-grid Valve

A better system, which is applicable to mains-operated sets as well as battery sets, is the use of a potentiometer to vary the voltage applied to the screen of the screened-grid valve. The connections are indicated in Figs. 5A and 5B, the former showing the arrangement for a battery-heated valve and the latter for an indirectly heated A.C. mains valve. The total value of the potentiometer resistance for the average battery valve should be 150,000 or 200,000 ohms, while for the A.C. valve a slightly smaller value, say 100,000 ohms is recommended.

Control by this method is comparatively smooth between fairly wide limits, but beyond these limits there is a risk of the valve becoming unstable in operation and falling into oscillation. Again, if the control is pushed too far, partial rectification may occur in the high frequency stage, resulting in cross-modulation and distortion.

Subject to this reservation, however, control by screen potentiometer is recommended for general use in receivers employing one or more screened grid valves.

The Multi-mu Valve

By far the most satisfactory method of controlling volume in the high frequency amplifying stage, however, is to use one of the many types of "multi-mu" valves as a high frequency amplifier. The multi-mu valve is a special form of screened-grid valve, its design being such that the working value of its "mútual conductance," and therefore its effective amplification, can be varied by adjusting the negative bias applied to its grid. At small values of grid bias the valve is extremely sensitive, and gives a high degree of amplification, but can handle without distortion only comparatively weak signals. On the other hand, as the negative grid bias is increased, the valve

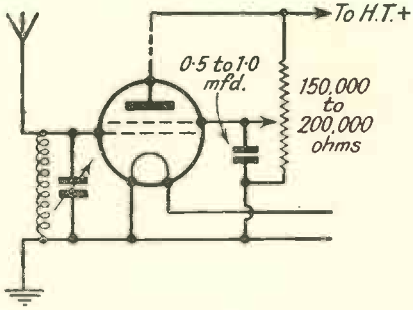


Fig. 5A.—Control of Volume in a Battery-operated Set by Potentiometer in the Screened-Grid Circuit.

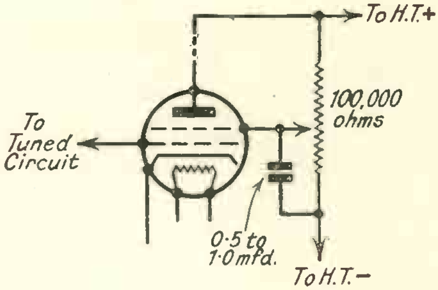


Fig. 5B.—Control of Volume in A.C. Mains Set by Screen Potentiometer.

becomes less sensitive, the overall amplification decreases, but the valve will accept and amplify without distortion very powerful inputs.

When using a multi-mu valve, therefore, little or no grid bias is required when weak or distant transmissions are being received, and maximum amplification is obtained. When, however, the local programme is tuned in, the grid bias must be increased, not only to reduce the volume of sound to a comfortable level, but also to avoid overloading of the high frequency amplifier.

Using Multi-mu Valves with Batteries

Multi-mu valves are available in battery types and indirectly heated A.C. mains types. Fig. 6 shows the connections for a battery-heated multi-mu valve, the variable grid bias being obtained by a potentiometer of 25,000 to 50,000 ohms connected in parallel with a 15-volt grid bias battery. It is not necessary to provide a separate grid bias battery for the multi-mu valve, the one battery supplying grid bias to this stage and to the low frequency stages.

Using Multi-mu Valves with A.C.

For A.C. multi-mu valves, where the maximum value of the grid bias may be as much as 40 to 50 volts, it is preferable to use "automatic" grid bias. This is obtained by connecting a resistance between the high tension negative terminal and the cathode of the multi-mu valve. The anode current of the valve passes through this resistance, and a drop of voltage occurs across it, so that the potential of the cathode is higher than that of the grid by the amount of the voltage drop in the biasing resistance.

Biasing Resistance should be in two Portions

Most A.C. multi-mu valves require a minimum bias of about 1·5 volts, even when working at maximum sensitivity, in order to avoid grid current and consequent distortion. It is, therefore, advisable to provide the biasing resistance in two portions, one of fixed value, calculated to give the minimum permanent bias, and the other adjustable. The circuit arrangement is indicated in Fig. 7, and shows, also, the potentiometer required for obtaining the correct voltage on the screen of the valve. Because the valves of various makers differ in characteristics, it is impossible to give the values for the various resistances. Most valve manufacturers, however, state the best values on the instruction sheets issued with the valves, or in their catalogues.

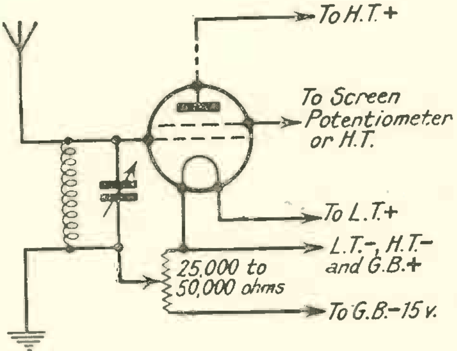


Fig. 6.—Volume Control by Battery-type Multi-mu Valve.

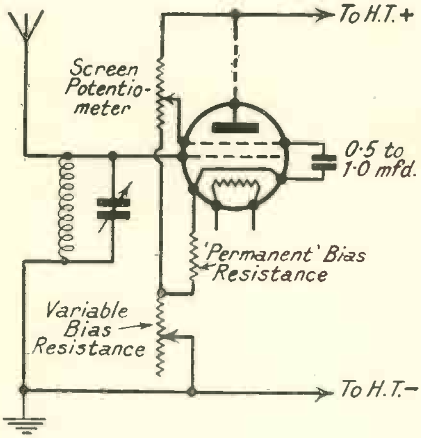


Fig. 7.—VOLUME CONTROL WITH A.C. MULTI-MU VALVE.

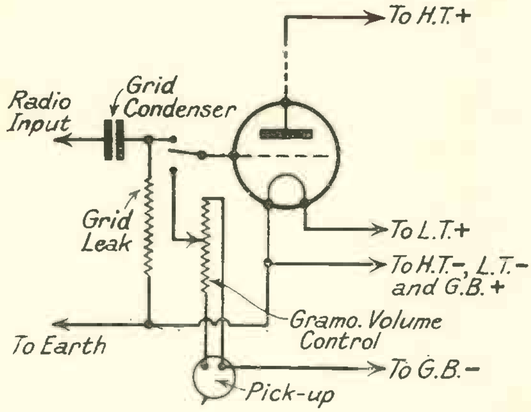


Fig. 8.—VOLUME CONTROL OF RADIO-GRAM, SHOWING CONNECTIONS FOR CHANGE-OVER SWITCH.

Volume Control in the Detector Stage

The only satisfactory method of controlling volume in the detector stage is by varying the degree of reaction. The ways of controlling reaction will be mentioned elsewhere in this work so that description here is unnecessary, and the device is only mentioned for the sake of completeness. It should be mentioned, however, that increasing reaction not only increases volume, but, to an extent, improves the selectivity of the set. Pushed to the extreme, however, it not only causes oscillation and re-radiation, but also spoils the quality of reproduction. Generally speaking, therefore, providing reasonable signal strength can be obtained without the use of considerable reaction, it is better to fit an additional form of volume control, and to avoid reaction except as an emergency measure for the reception of distant stations.

Post - detector Volume Control

Control of volume by limiting the input to the grid of one of the low frequency valves may be simply arranged by fitting a potentiometer across the input circuit. Such an arrangement is commonly used for controlling the low frequency amplifier portion of a receiver which is also employed for reproducing gramophone records. In this case, the potentiometer is connected across the pick-up as indicated in Fig. 8. Use a resistance of from 100,000 to 500,000 ohms.

Connections for Transformer Coupling

Fig. 9 shows the arrangement applied to a later stage amplifier, the diagram on the left giving the connections when the previous coupling circuit is an intervalve transformer.

Connections for R.C. Coupling

On the right, the potentiometer is used in conjunction with a resistance-capacity coupling circuit. Here, the potentiometer, which should be of 500,000 ohms, is connected between the coupling condenser and the grid bias battery.

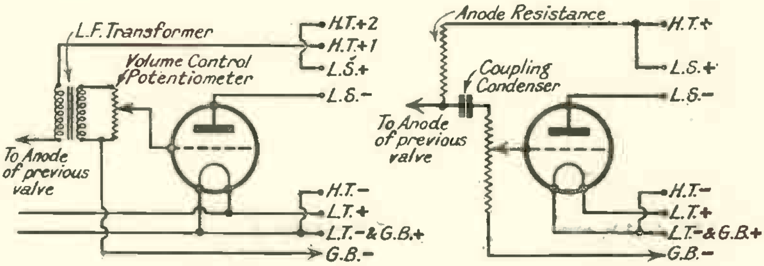


Fig. 9.—VOLUME CONTROL IN LOW FREQUENCY STAGES.

Left—Transformer-coupled stage.
Right—Resistance-capacity coupled stage.

MAKING A SELF-CONTAINED PEDESTAL RECEIVER

By EDWARD W. HOBBS, A.I.N.A.

THE receiving set described here and on the Presentation Plate has been specially designed for readers of "Complete Wireless" who wish to enjoy radio reception at its best, without trouble or difficulty, from the National, Regional and principal foreign stations.

The cabinet work is simple and straightforward, but presents several novel and interesting features specially incorporated to enhance the tonal qualities of the instrument and ensure the best results from the moving coil loud speaker, which is placed in the upper part of the pedestal and has the usual protective fret and sound outlet on the underside.

Fig. 1.—THE COMPLETED RECEIVER.
This handsome wireless set can be used indoors or out: is entirely self-contained and has remarkable tonal quality.

Details of the Radio Set

The receiving set comprises four valves in the sequence of a screen-grid high-frequency amplifier, a detector on the leaky grid principle for maximum sensitivity followed by a two-stage low frequency amplifier. The valves, components and grid bias battery are disposed beside the loud speaker cone and are appropriately screened and earthed.

Battery Connections

The high and low tension batteries are located in the compartment beneath the lower shelf. Connections from the L.T. and H.T. batteries to the set are taken up one leg of the pedestal, the H.T. + top lead from the H.T. battery is taken up the opposite leg.

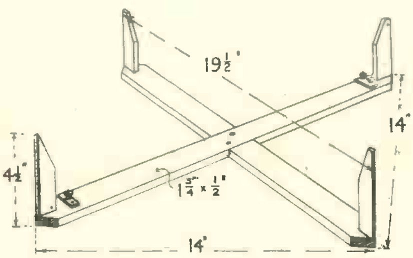


Fig. 2.—FORMER FOR FRAME AERIAL.

The Frame Aerial

The frame aerial is horizontal and is placed

LIST OF COMPONENTS

Parts for the Pedestal

4 Gramophone Cabinet Legs, 36 inches long.
1 Table Top, 19 inches square, ¾ inch thick.
1 Piece 5-ply Wood, 16½ inches square, ¾ inch thick.
3 Pieces 5-ply Wood, 16½ inches long, 6 inches wide, ¾ inch thick.
2 Pieces 3-ply Wood, 16½ inches square, ½ inch thick.
4 Pieces 3-ply Wood, 16½ inches long, 5 inches wide, 3/16 inch thick.
4 Strips Mahogany, 1¼ inch wide, ¼ inch thick, 18 inches long.
Astragal Moulding, 16 feet run, ½ inch wide, or other style moulding to choice.
4 Castors, or a set of Chair Slides.
4 Brass Angle Plates about 1 inch long.
1 Dozen Round Head Brass Screws, ⅝ inch long, No. 6 gauge.
1 Ounce Fine Panel Pins, ¾ inch long, No. 18 gauge.
1 Ounce Fine Panel Pins, 1½ inches long, No. 16 gauge.
1 Small Tin Wood-filler, 1 Small Packet Mahogany (or Oak) Water Stain, ½ pint French Polish or ready-to-use Polish.
1 Pair of Brass Hinges and Screws, 1 Small Spring Ball Catch, 1 Small Knob.

The legs can be had either in Whitewood, Oak or Walnut, as desired, and all the plywood should be bought ready " faced " to match (*Sinclairs, of Harrow*).

Components and Parts for the Receiving Set

Sub-base.—Plywood, ¼ inch thick, 15 inches long, 6½ inches wide.
Panel.—Plywood, 3/16 inch thick, 14¼ inches long, 6 inches wide.
Aluminium Partition Screen.—6 inches × 6½ inches.
Aluminium Foil.—1 Piece 14¼ inches long, 6 inches wide.
Tuning Condensers.—Two Solid Dielectric, each ·0005 variable condensers (*Telsen*).
Reaction Condenser.—One, ·0003 Bakelite Dielectric with knot (*Lissen*), Two slow motion dials (*Millgate* 88).
Valve Holders.—One horizontal mounting, three standard 4-pin holders (*Benjamin*).
Tuning Coil.—1 shielded dual range coil (*Lissen*).
Chokes.—1 screened H.F. choke (*Wearite*), 1 disk type H.F. choke (*Lissen*).
Wave-Range Switch.—1 3-point shorting switch (*Bulgin*).
On–Off Switch.—1 filament switch (*Lotus*).
Fixed Condensers.—3 1 mfd. fixed (*T.C.C.*) 1 each fixed condensers, with values of ·0002 mfd., ·0003 mfd. and ·006 mfd. (*Dubilier*) Type 670. 1 small fixed condenser, ·0003 mfd. (*Dubilier*) Type 665.
1 " Transcoupler " L.F. coupling unit (*Bulgin*).
Spaghetti Resistances.—1 each 20,000 ohms 50,000 ohms. (*Lewcos*).
Grid Leak.—1 2-megohm, and 1 ½-megohm grid leak with wire ends. 1 grid leak holder (*Lissen*).
Connecting Wire.—1 coil each, red, yellow, blue Glazite (*Lewcos*).
Coloured Sleeving.—About 2 feet (*Lewcos*).
Flexible Wire.—About 100 feet (*Lewcoflex* 14/36 V.I.R.).
Anode Connector.—1 (*Belling Lee*).
Sundries.—2 spade terminals, 6 wander plugs, 4 bolts and nuts for fixing loud speaker chassis, 3 terminal bolts and nuts, 1 piece ebonite, 3 inches × 1 inch × ¼ inch. 18 inches of ⅛-inch diameter ebonite rod, 1 piece ebonite 2 inches long, and 1 piece 1 inch long each, ¾ inch wide, ¼ inch thick, 1 H.T. " Wander Fuse " (*Belling-Lee*).
Frame Aerial Wire.—100 yards, multi-stranded 9/40 (*Lewcos*).
Valves.—1 each 215 S.b, 210 H.L., 210 H.F., 220 P.A. (*Cossor*).
Batteries.—1 120 volt H.T. battery, 1 9-volt grid bias battery, 1 2-volt " Exide " accumulator (*Pertrix*).
Loud Speaker.—1. "Motor Minor" moving coil permanent magnet loud speaker complete (*Tekade Radio*).

within the lower compartment, and is comparatively non-directional.

The batteries are located in the lower compartment and stand upon a platform made of thick cardboard or three-ply wood placed on the frame aerial former. This arrangement brings the batteries in the middle of the frame and to enable them to be withdrawn, as shown in Fig. 19, the aerial is wound on a special wooden former so arranged

Fig. 2A.—The Pedestal Legs.
These are shaped and dimensioned as here shown and have a hollow inner edge.

that it and the batteries can be pulled out like a drawer whenever in need of attention, for which purpose long flexible leads are fixed to the aerial and the batteries.

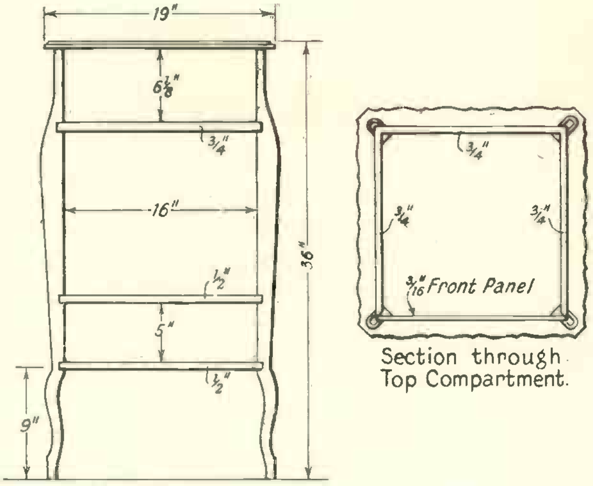


Fig. 3.—DETAILS OF THE PEDESTAL.

This shows the arrangement of the two compartments and gives dimensions of the parts.

Materials and Parts

With regard to the list of components and materials needed for this set, named components can be relied upon for the purpose, but others of equivalent quality and electrical value may be substituted.

THE CABINET WORK

The best procedure is first to make the pedestal table, then fix the loud speaker, and finally, fit up the receiver ; for the sake of regularity this order is maintained in this description.

All the cabinet work can be made up by hand from plain wood, or a set of machined parts specially prepared for this set can be obtained ready to assemble from Sinclairs' Joinery Works, Vaughan Road, Harrow, which is a great boon to those not too well versed in woodwork.

Preparing the Legs

If the machined parts are not used, obtain four cabinet gramophone legs and a 19½-inch table top.

First prepare the legs, which are rectangular in cross-section and tapered for a portion of their length, and are hollowed diagonally from top to bottom on the inner edge.

A V-shaped recess is formed along the inside edge of each leg for the dual purposes of supporting the wood panels and concealing the various wires.

Mark upon each leg the positions of the top and bottom compartments and shelves, as given in Fig. 3, then prepare four rectangular strips of wood to fit neatly into the recesses in the legs so as to fill in the parts between the two compartments. Then plane off the inner corners of these strips—as shown in Fig. 4—and cut a deep

Fig. 4.—SECTION OF LEG.

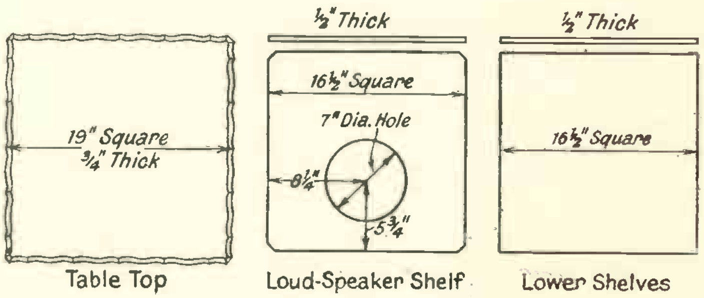


Fig. 5.—TABLE TOP AND SHELVES.

The shape and sizes of the table top and the shelves. Three of the latter are required, one is ¾ inch thick and has the loud speaker fret, the remainder are ½ inch thick and are plain.

groove in the inner edge of each leg from just below the underside of the bottom compartment to the top.

This groove is also shown in Fig. 4, and this, together with the flat already worked on the filling strip, forms the hollow space for the wires.

The Table Tops

The next proceeding is to prepare or purchase the various table tops and shelves which form the basis of the two compartments. These are fully detailed in Fig. 5, and are readily shaped with a plane, chisel and saw. A neat moulding may be worked on the visible edges with the aid of a reeding plane; alternatively, a ready-made moulding can be purchased and be glued and pinned in place.

Now cut the diagonal notches in the legs for the shelves to fit into — as shown in Fig. 6—then fit the parts together to see that everything is correct thus far.

The Lower Shelf

Next prepare the lower shelf on which the loud speaker is mounted, and likewise the three main panels for the top compartment.

These four pieces must be very thick, rigid and very securely attached to the legs; the best material to use is 5-ply board, $\frac{3}{4}$-inch thick, or Lamin board, $\frac{3}{4}$-inch thick. The front piece, which forms the panel, is only $\frac{3}{16}$-inch thick.

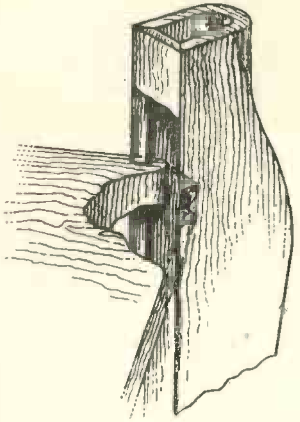


Fig. 6.—Fixing Shelves to Legs.

Notches are cut diagonally across the legs for the shelves to fit into.

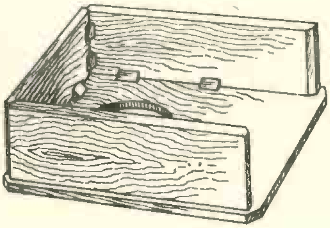


Fig. 7.—Assembling the Top Compartment.

The bottom and sides form the the baffle-board, the joints are glued and pinned together and strengthened at the corners by glue blocks.

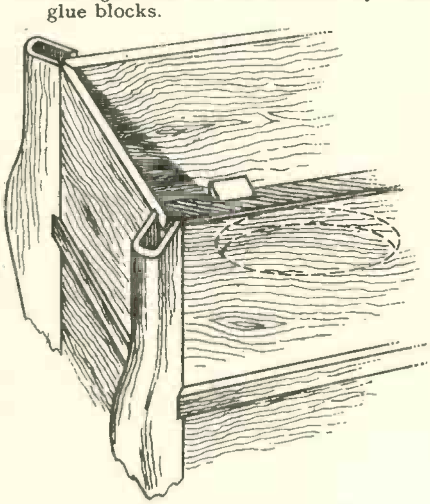


Fig. 8.—Fixing Legs to Top Compartment.

Building the Baffle Board

It is well known that the tonal quality of a moving coil speaker is improved greatly by the use of a large, non-resonating baffle board, which in this case is represented by the bottom and four sides of the top compartment on the pedestal.

To ensure rigidity and to reduce the likelihood of the woodwork developing objectionable resonances or vibrations of its own, the three sides are glued and screwed to the bottom, and the inner corners filled in with triangular fillets glued into place, as shown in Fig. 7.

Joining the Sides and Legs

The junction of the sides with the legs is similarly effected in principle, and the details can be seen by a glance at Fig. 8, which is partly in section and shows how the sides butt against each other and are glued and pinned to the legs, and are further stiffened by internal glue blocks in the corners.

To make the sides, prepare two opposite side pieces, then glue and screw on to each end the inner triangular blocks.

Now fit the back piece to the first pair, glue and screw them together, and when dry, plane the top and bottom edges to make them flat, and glue and screw on the bottom member. Glue and pin the top compartment to the legs at the same time that the bottom compartment is fixed, taking care to keep all the corner grooves clear.

WITH PART 2.

DESIGN CHART

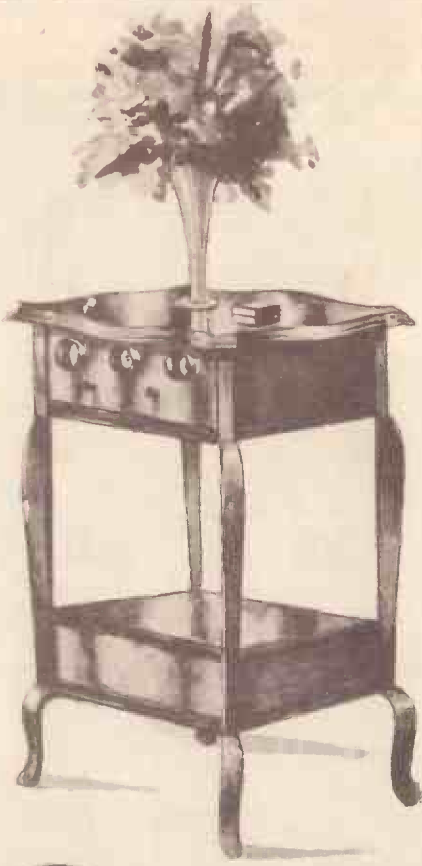
for Newnes "Complete Wireless"

SELF-CONTAINED PEDESTAL RECEIVER

THIS receiver has many features of interest. It is entirely self-contained; the receiving set and moving coil loud-speaker are in the upper compartment, the frame aerial, which is practically non-directional, and batteries are concealed in the lower compartment.

It can be used anywhere indoors or out; National, Regional, and the principal foreign stations are received at ample strength and with remarkable fidelity and tonal qualities.

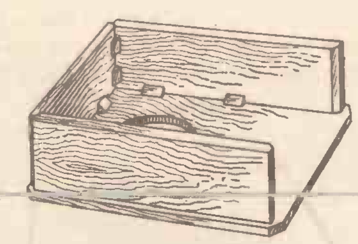
Key stages in the home construction of the set are illustrated, and these, with the aid of the circuit diagram, panel, and baseboard lay-out and Uni-view Wiring Diagram showing the path of every wire, will enable any one to build a replica.



The Completed Pedestal Receiver

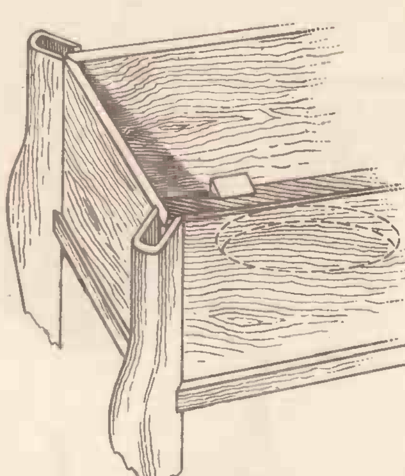
Stage 1.

Work a deep groove along the inside of each leg, and fit covering strips over the groove between top and bottom compartments.



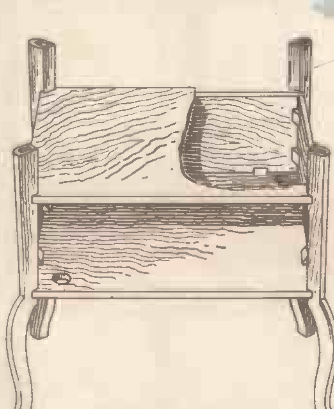
Stage 2.

Build up top compartment, cut 7-inch diameter hole for loud-speaker. Leave front open for set to slide in.



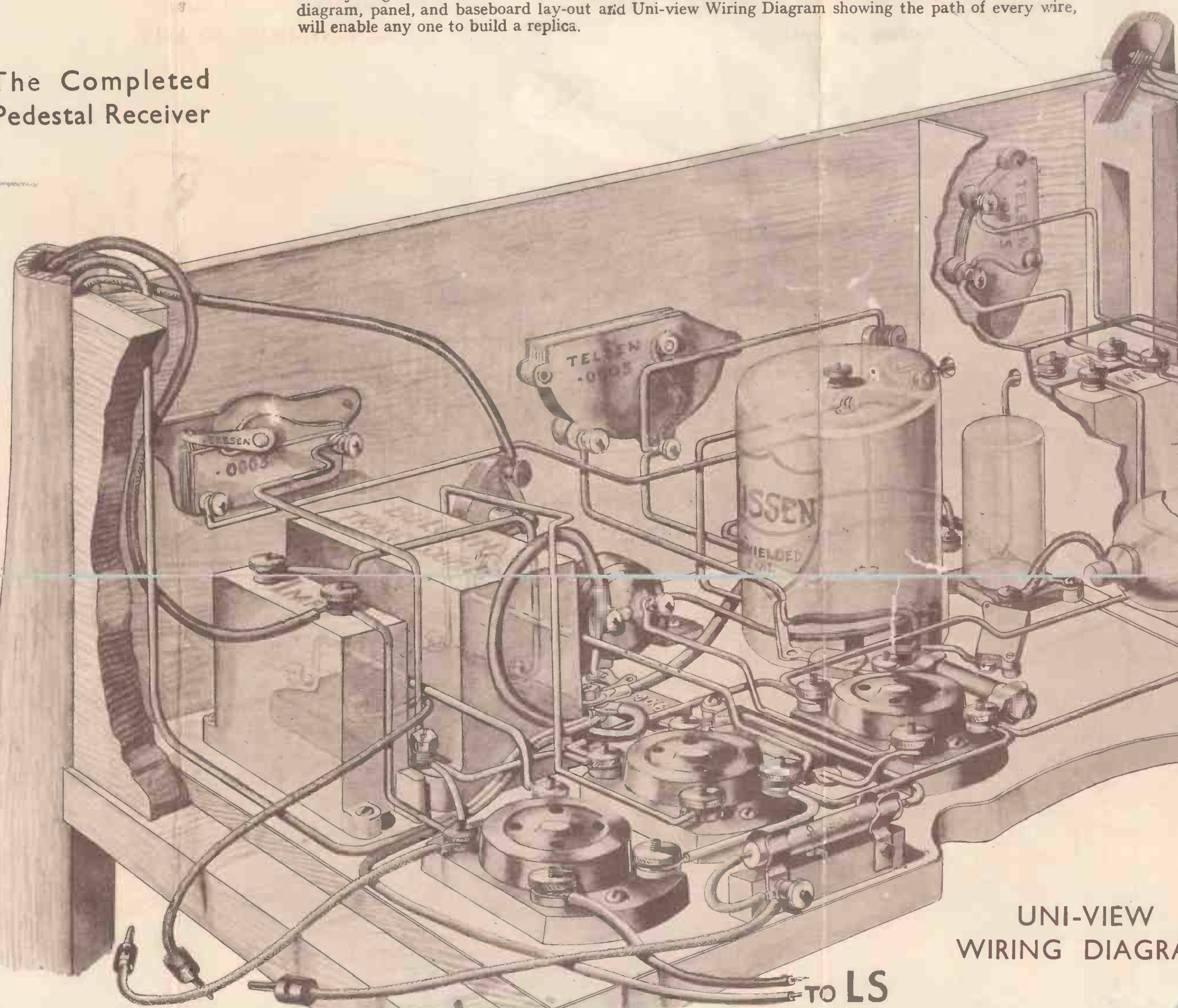
Stage 3.

Notch the legs for base of top compartment, then glue and pin the legs to it, leaving ¼ inch projecting above the upper



Stage 4.

Fix bottom compartment to legs, hinge the door at back, drill holes through the bottom for battery leads to pass. Make Frame Aerial which is to be inserted in this compartment. Bolt loud-speaker to top compartment.



UNI-VIEW WIRING DIAGRA

LIST OF COMPONENTS.

Parts for the Pedestal.

4 Gramophone Cabinet Legs, 36 inches long.

1 Table Top, 19 inches square, ¾ inch thick.

1 Piece 5-ply Wood, 16½ inches square, ¾ inch thick.

3 Pieces 5-ply Wood, 16½ inches long, 6 inches wide, ¾ inch thick.

2 Pieces 3-ply Wood, 16½ inches square, ½ inch thick.

4 Pieces 3-ply Wood, 16¾ inches long, 5 inches wide, 3/16 inch thick.

4 Strips Mahogany, 1¼ inch wide, ¼ inch thick, 18 inches long.

Astragal Moulding, 16 feet run, ½ inch wide, or other style moulding to choice.

4 Castors, or a set of Chair Slides.

4 Brass Angle Plates about 1 inch long.

1 Dozen Round Head Brass Screws, ⅝ inch long, No. 6 gauge.

1 Ounce Fine Panel Pins, ¾ inch long, No. 18 gauge.

1 Ounce Fine Panel Pins, 1½ inches long, No. 16 gauge.

1 Small Tin Wood-filler, 1 Small Packet Mahogany (or Oak) Water Stain, ½ pint French Polish or ready-to-use Polish.

1 Pair of Brass Hinges and Screws, 1 Small Spring Ball Catch, 1 Small Knob.

For Frame Aerial—
4 ft. of 1¾" × ½" Oak or Deal.
18" of 1½" × ⅜" Oak or Deal.

All the plywood should be bought ready "faced" to match the legs.

(*Sinclairs of Harrow*)

Order of Wiring.

1. Run L.T. neg. wire from M.P. of reaction condenser to E on transcoupler; to 1 mf. condenser and 4 valve filament terminals, thence to baseboard foil, two 1 mf. condensers, aerial tuning condenser (M.P.), and end of frame aerial windings.

2. L.T. plus wire from on-off switch to 4 valve filament terminals.

3. Connect 2 megohm leak in clips across G and F plus of detector valve terminals.

4. Reaction condenser to No. 6 on coil.

5. Connect fixed condensers, ·0002 to 1st H.F. choke; ·0003 to G of detector valve; ·006 to G of 3rd valve.

6. Tuning condenser (F.P.) to grid condenser, No. 1 on coil, and to ·0002 condenser.

7. Connect from terminals on transcoupler, A to anode of 3rd valve; "low" to 1 mf. condenser; "high" to H.T. plus, and by 20,000 ohms spaghetti to first H.F. choke, by 50,000 ohms spaghetti to 2nd H.F. choke. Connect G to grid of 4th valve. G.B. to grid bias negative 2.

8. Tuning condenser (M.P.) to No. 2 on coil, top terminal of wave-change switch and to baseboard foil.

9. Wave-change switch 2nd terminal to No. 3 on coil; 3rd terminal to tap on frame aerial.

10. A.T.C. to grid of 1st valve and start of frame aerial.

11. 1st H.F. choke to 1 mf. condenser.

12. Condenser side of 1st H.F. choke to anode of S.G. valve.

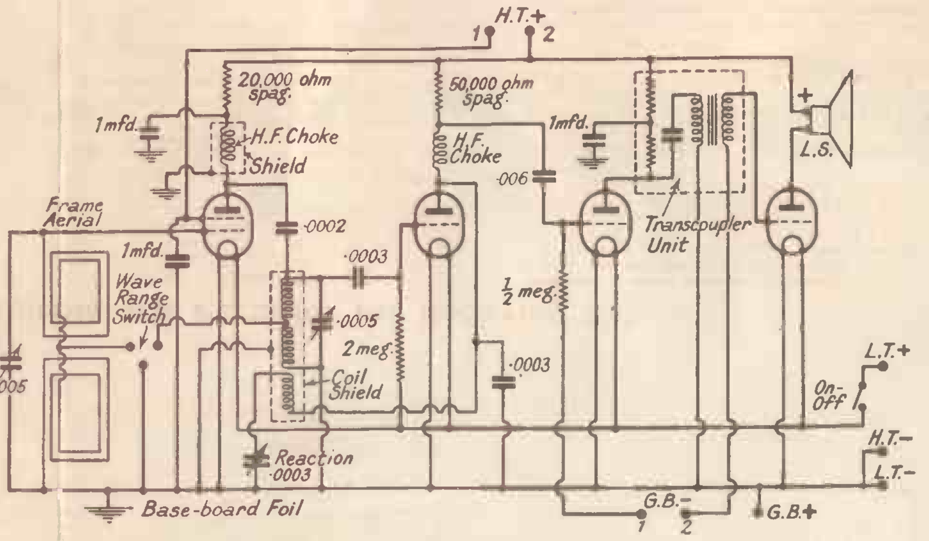
13. H.T. plus tap to screening grid of 1st valve and to 1 mf. condenser.

14. 2nd H.F. choke to A of detector and to ·0003 decoupling condenser; other side of condenser to baseboard foil.

15. Connect ½ megohm leak between G of 3rd valve and G.B. negative 1.

16. Anode of 4th valve to loud-speaker.

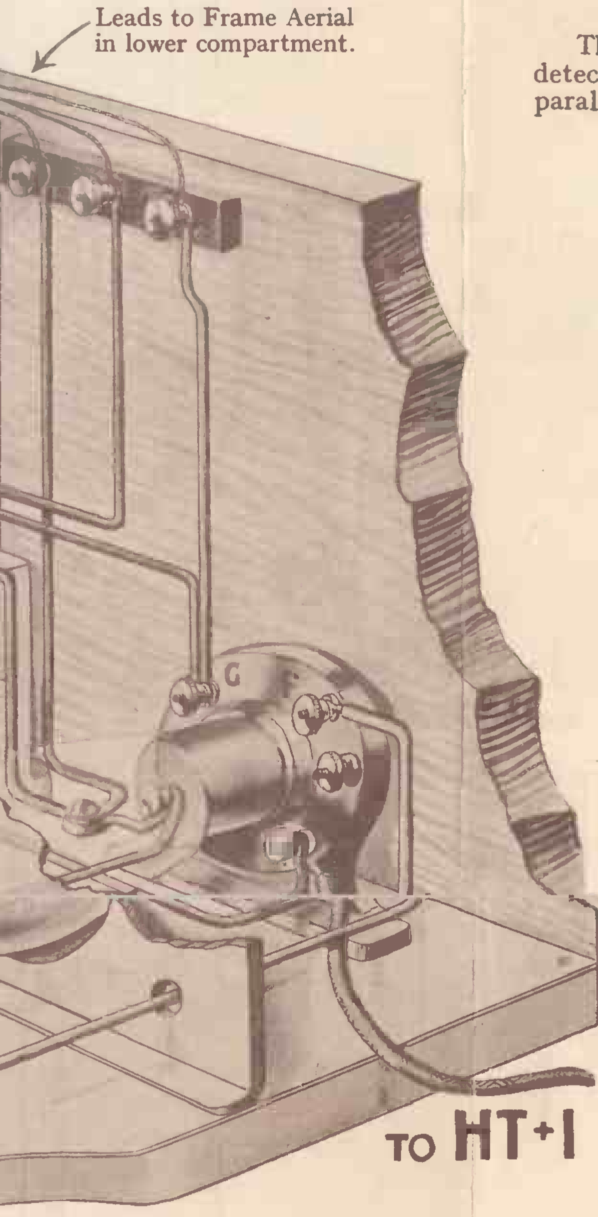
17. Connect battery leads, G.B. plus to L.T. minus on 4th valve. H.T. and L.T. negative to negative side of last 1 mf. condenser; L.T. plus to on-off switch. H.T. plus to loud-speaker.

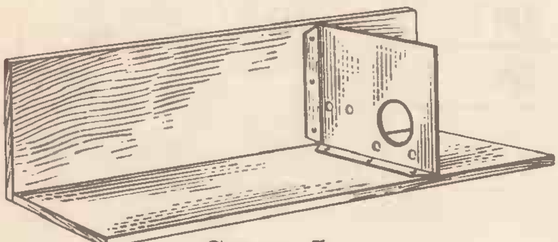


Circuit Diagram.

The circuit embodies a screen-grid H.F. amplifier, detector, a stage of resistance capacity coupling, and a parallel feed L.F. amplifier.

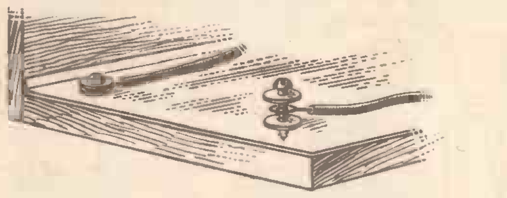
Leads to Frame Aerial in lower compartment.





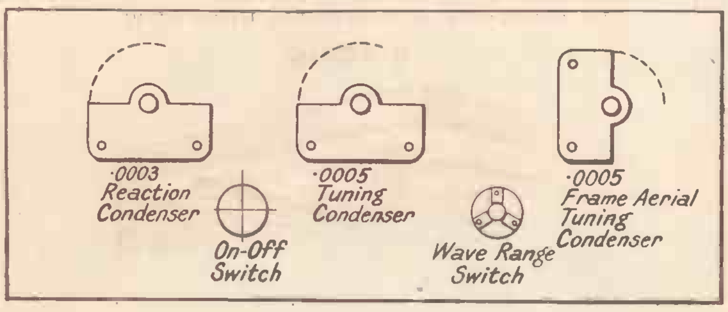
Stage 5.

Cover baseboard with foil, and fix panel to front, fix aluminium screen, and adjust to slide bodily into front of top compartment.



Stage 6.

Make earth connections to baseboard foil with a rounded screw and aluminium washers.

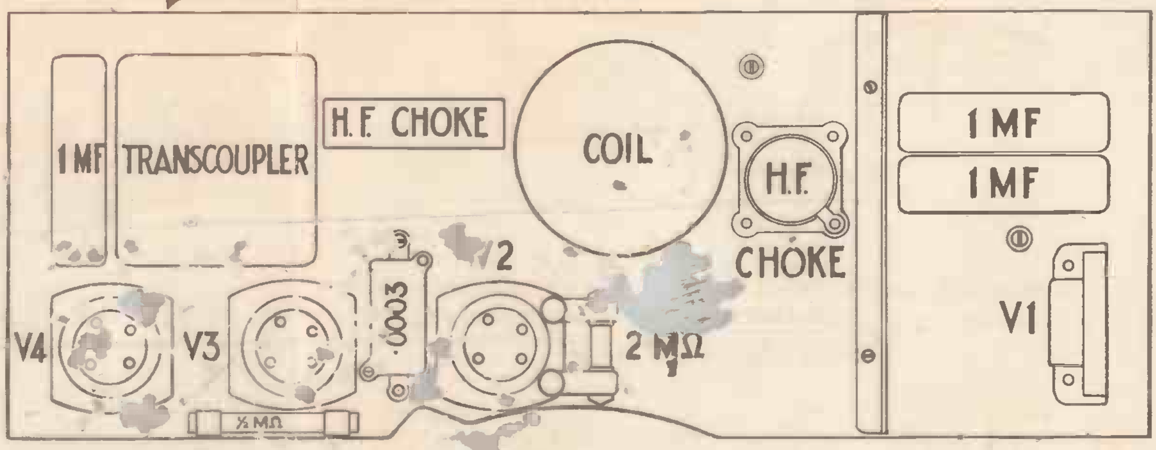


Stage 7.

Fix components to panel as here shown.

AM

Sub-base 15″ × 6½″



Stage 8.

Screw components to baseboard as here shown.

Components and Parts for the Receiving Set.

Sub-base.—Plywood, ½ inch thick, 15 inches long, 6½ inches wide.

Panel.—Plywood, 3/16 inch thick, 14½ inches long, 6 inches wide.

Aluminium Partition Screen.—6 inches × 6½ inches.

Aluminium Foil.—1 Piece 14½ inches long, 6 inches wide.

Tuning Condensers.—2 Solid Dielectric, each ·0005 variable condensers (*Telsen*).

Reaction Condenser.—1 ·0003 Bakelite Dielectric with knob (*Lissen*).

1 Slow Motion Dial (*Millgate* 88).

Valve Holders.—1 horizontal mounting, 3-standard 4-pin holders (*Benjamin*).

Tuning Coil.—1 shielded dual range coil (*Lissen*).

Chokes.—1 screened H.F. choke (*Wearite*), 1 disk type H.F. choke (*Lissen*).

Wave-Range Switch.—1 3-point shorting switch (*Bulgin*).

On-Off Switch.—1 filament switch (*Lotus*).

Fixed Condensers.—3 1 mfd. fixed (*T.C.C.*), 1 each fixed condensers, with values of ·0002 mfd., ·0003 mfd. and ·006 mfd. (*Dubilier*), Type 670. 1 small fixed condenser, ·0003 mfd. (*Dubilier*), Type 665.

1 "Transcoupler" L.F. coupling unit (*Bulgin*).

Spaghetti Resistances.—1 each 20,000 ohms, 50,000 ohms (*Lewcos*).

Grid Leak.—1 2-megohm, and 1 ½-megohm grid leak with wire ends. 1 grid leak holder (*Lissen*).

Connecting Wire.—1 coil each, red, yellow, blue, Glazite (*Lewcos*).

Coloured Sleeving.—About 2 feet (*Lewcos*).

Flexible Wire.—About 100 feet (*Lewcoflex*), 14/36 V.I.R.

Anode Connector.—1 (*Belling Lee.*)

Sundries.—2 spade terminals, 6 wander plugs, 4 bolts and nuts for fixing loud-speaker chassis, 6 terminal bolts and nuts, 1 piece ebonite, 3 inches × 1 inch × ½ inch. 18 inches of ¼-inch diameter ebonite rod, 1 piece ebonite 2 inches long, and 1 piece 1 inch long each. ¾ inch wide, ¼ inch thick, 1 H.T. "Wander fuse" (*Belling Lee*).

Frame Aerial Wire.—100 yards, multi-stranded, 9/40 (*Lewcos*).

Valves.—1 each 215 S.G., 210 H.L., 210 H.F., 220 P.A. (*Cossor*).

Batteries.—1 "Pertrix" 120-volt H.T. battery, 1 9-volt grid bias battery ("Pertrix"), 1 2-volt "Exide" accumulator.

Loud-Speaker.—1 "Motor Minor" moving coil permanent magnet loud-speaker complete (*Tekade Radio*).

The Bottom Compartment

This consists of the top and bottom shelves — as detailed in Fig. 9—three fixed sides and one hinged side. The fixed parts are made up and fitted as already described, the loose portion or door is hinged as usual and provided with a small knob or thumb catch—as shown in Fig. 10—and a spring catch to keep it closed.

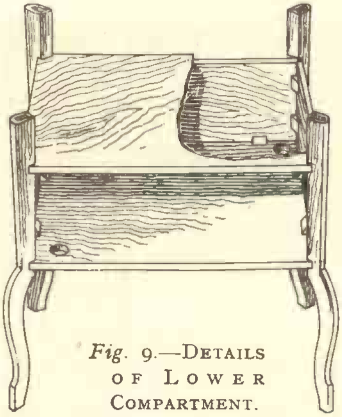


Fig. 9.—Details of Lower Compartment.

Sectional view showing the battery space, holes for battery leads and arrangement of hollow legs.

Air Gap or Breather Holes

Assemble the two compartments on the legs, note that the tops of the legs stand about ¼-inch above the top edge of the sides — as shown in Fig. 11—to leave an air gap, or breather holes, and that the outer top, or table surface, is attached to the sides by means of small brass angle plates and screws to ensure strength and to enable it to be removed readily at any time.

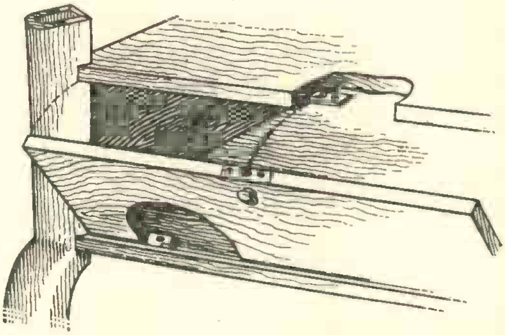


Fig. 10.—Details of Door.

The door on the lower compartment is hinged to the bottom shelf and secured in the close position by a spring catch.

How to Prepare the Exterior

Clean down the exterior with fine sandpaper, then stain it with water stain, allow to dry, again rub down and give a coat of wood filler. After this has dried, rub down again with fine sandpaper, follow this by a rub over with a linen pad dipped in the water stain and worked in the direction of the grain, then give one coat of thin shellac varnish. Leave the final polishing until the receiving equipment and other parts have been fitted and tested.

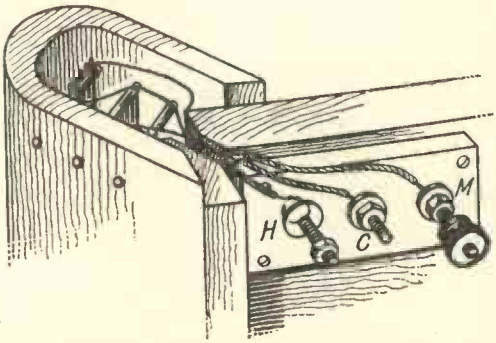


Fig. 11.—Aerial Terminal Block.

The ebonite plate is screwed to one face of the cabinet and the ends and middle tapping of the aerial windings clamped to the terminals. The windings are spaced by ebonite bars through the legs.

Making the Aerial Former

The aerial former consists of two pieces of smooth oak or deal, each 19½ inches long, 1¾ inch wide and ½ inch thick halved together (Fig. 15) at the centre and jointed with glue and screws.

Four uprights each 4 inches long, 1½ inches wide and ⅜ inch thick are shaped (Fig. 2) and glued. screwed and nailed to each corner after the notches have been cut on the outside edges.

A separate notch for each wire is most desirable, but when deal or other soft wood is used it is impracticable to cut them with anything bigger than a fretsaw; consequently when this is not available it is best to make ten equally spaced saw cuts and wind every fifth turn into one of them, spacing the other turns equally between the notches. An upright notched in this way is shown in Fig. 16 and also the mode of nailing and screwing it to the frame.

Terminal Blocks

Fit to one corner of the star frame close up to the upright, an ebonite plate with a single terminal upon it, and on the opposite end of the same arm, near the other upright fit an ebonite block with two terminals on it—as shown in Fig. 18.

Drill a single small hole through the bottom part of the upright next to the single terminal; drill a small hole through the opposite upright at a distance of 1⅛ inches from the bottom, for the end of the medium-wave winding and the start of the long-wave winding, also drill another small hole at the top of the same upright for the end of the long-wave winding.

Winding the Aerial

The aerial is wound in two distinct sections, commencing from the bottom with the medium-wave winding of thirteen turns of No. 22 D.S.C. copper wire, for which purpose ¼ lb. of wire will be needed.

Commence this winding by putting the wire through the bottom hole, turning it around the back and again through the hole. Bare the end of the wire and make it fast to the terminal. Then make thirteen complete turns and finish at the opposite upright, fastening off the wire and making it fast to one of the pair of terminals, called the grid terminal.

The long-wave winding consists of forty turns of No. 30 D.S.C. wire—that is, about 3 oz., and is commenced at the point where the medium-wave winding ends and is fastened off and fixed to the same terminal, which is called the tapping terminal.

Make forty complete turns of the wire in the same direction as the first, then finish and fasten off as before and attach the end to the second terminal—called the earth terminal.

Connecting Up the Aerial

Place the aerial in the lower compartment with one terminal block to the left, pass a single flexible wire down the left hand leg (as seen from the front), connect the upper end to the grid terminal on the block in the case and lead the lower end in through a hole in the bottom corner and connect it to the grid terminal on the frame, leaving sufficient slack to enable it to be withdrawn.

Run two wires down the opposite leg connecting one to the centre terminal on the upper block and to the tapping terminal on the frame. Connect the other to the earth terminal—the one nearest the panel—at the top and to the earth terminal on the frame at the bottom, leading them in through a hole near the leg as before.

Cut a piece of card or plywood about 12 inches square—place it on the star frame and put the H.T. and L.T. batteries upon it and connect them up to the set by flexible leads in the other pair of hollow legs.

External Connections

If the increased range and power from the set is desired, an earth wire can be attached to the earth terminal on the frame and connected to a water pipe or other good earth. This does not affect the tuning of the set, but increases its strength and range, but to attain the maximum in this direction, connect an indoor or outdoor aerial in the usual way to the grid terminal of the frame. This may in some cases affect the tuning range of the set, and to correct this an additional and variable condenser should be fixed in the back part of the top compartment and connected either in series or in parallel with the grid lead from the frame and the grid terminal on the set.

An average valve is about ·0002, and if the set does not tune low enough put the condenser in series, but if the set

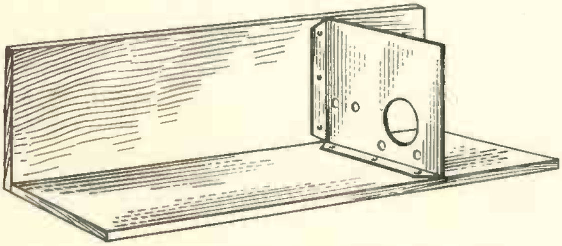


Fig. 12.—BASEBOARD, PANEL AND SCREEN.
The baseboard is faced with aluminium foil, the screen is fixed to base and to panel.

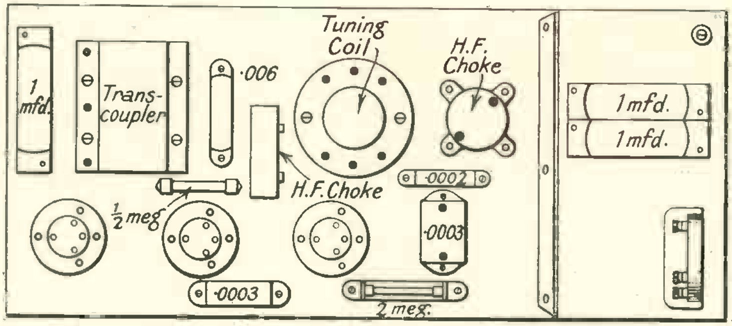


Fig. 13.—ARRANGEMENT OF COMPONENTS ON BASE.

This outline diagram indicates the locations of the components on the baseboard

does not tune high enough put the condenser in parallel.

THE RECEIVING CIRCUIT

The next step is to fit up the components and assemble the receiver. The circuit—shown in Fig. 17—is one that embodies highly desirable features for a portable set. The screen-grid first valve is a veritable station-getter and in conjunction with the tuned frame aerial and the tuned inter-valve coupling coils, ensures adequate selectivity.

Reaction is provided on the coupling coils and is controlled in the usual way by a ·0003 variable condenser.

A leaky grid detector is used on account of its sensitivity, while for volume and purity one stage of resistance coupling is followed by a transformer coupled power stage which completes the circuit to the permanent magnet moving coil loud speaker.

The Baseboard

The most convenient way of making up the set is to mount all the components on a plywood panel or sub-base, measuring 14¼ × 6 × ¼ inch. Glue and pin a piece of ⅛-inch plywood vertically to the front edge, cover the top of the base and the back edge of the front panel with aluminium foil held down by small round-headed brass screws. Next screw on the aluminium shield for the first valve, placing it at a distance of 3½ inches from the aerial input end—as shown in Fig. 12. See that the hole in this screen is suitable for the selected valve, and drill clearance holes for the connecting wires to pass through. Trim up this structure so that it will slide bodily into the top compartment and fix it by screws to two fillets fixed inside the case.

Mounting the Components

Next, screw the various components into their places, spacing and arranging them as shown in Fig. 13, beginning with the horizontal mounting valve holder; next comes the two 1-mfd. condensers. The H.F. choke is placed beside the shield.

The next group comprises the dual range shielded tuning coil, the S.G. anode condenser, grid detector condenser, detector valve holder and grid leak.

The remaining two valve holders are then mounted and are followed by the decoupling condenser, L.F. coupling unit, H.F. choke and the last condenser.

Arrangement of Components on Panel

Mount on the panel the two tuning

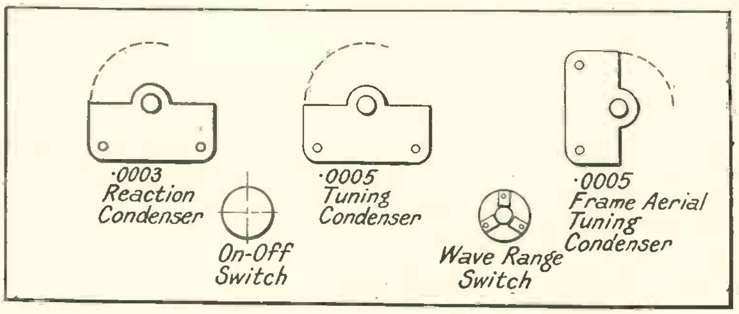


Fig. 14.—ARRANGEMENT OF COMPONENTS ON PANEL.

Back view in outline showing the whereabouts of the panel components.

condensers, wave - range switch, reaction condenser and on-off switch, placing them as shown in Fig. 14.

There is just room for the components when arranged in this way, but there is no space to spare, and if components of other makes than those specified are used it may be necessary to space them differently, but in any case the same relative arrangements should be maintained.

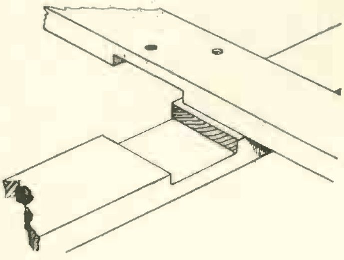


Fig. 15.—Halved Joint for Star Frame.

Wiring the Set

Next comes the wiring, which is one of the most important jobs of all. Essentials are short direct wires adequately insulated where necessary, mechanically clean contact surfaces and securely tightened fasteners.

Tinned copper wire enclosed in coloured sleeving or Lewcos "Glazite" is the best material to employ for the main wiring; well insulated flexible wire is used for the battery leads and for the frame aerial connections.

Obtaining Access to Components

Owing to the very compact arrangement of the components it will be found helpful to remove some of them while the wiring is in progress so as to get plenty of room for access to the various terminals and be certain of good connections.

Connections to Aluminium Foil

At certain points connections have to be made to the aluminium foil covering the baseboard; these can be made efficiently by using a round-headed screw with two brass washers on it and clamping the wire between them.

Where to Begin the Wiring

Begin the wiring by connecting up the aerial tuning condenser and the fixed condensers; several of them can be clipped direct to the valve holders as shown on the "Uniview" diagram, and the screen-grid valve holder, then complete the low-tension circuit for the filaments, connect a wire to one side of the on-off switch and take it to a terminal fitment on the nearest valve holder on the plus side. Then connect from the other terminal on the switch a flexible wire long enough to pass down through one of the legs of the pedestal and connect to plus side of the L.T. battery. A similar flexible is used for the L.T. and H.T. negative from the terminal block and a lead is also taken to a screw clamp on the baseboard foil.

Wave-range Switch

The wave-range switch is of the three-point type and is wired so that it short circuits the long-wave sections of the inter-valve coil and the long-wave winding of the frame aerial. A flexible connects between one terminal of the switch and the middle terminal of the frame windings; the opposite terminal on the switch is connected to the middle terminal of the dual-range tuning coil, the remaining terminal on the switch is connected to the tuning condenser, the dual-range coil and to earth—that is—to the aluminium foil on the baseboard.

Points about the "Transcoupler"

Special note should perhaps be made of the Bulgin "Transcoupler," which consists of a complete parallel-feed transformer arrangement in one unit and comprises within itself a tapped anode resistance, L.F. transformer and condenser.

The tapping point on the resistance is connected through a 1 mfd. condenser to earth, thus simplifying the wiring and utilising the two portions of the resistance, one as a decoupling resistance, the other as an anode resistance.

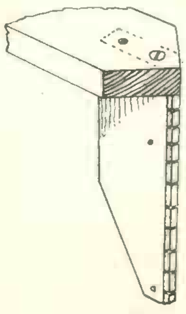


Fig. 16.—Corner Upright.

Assembling and Testing

There are two high-tension plus leads, one feeds the main

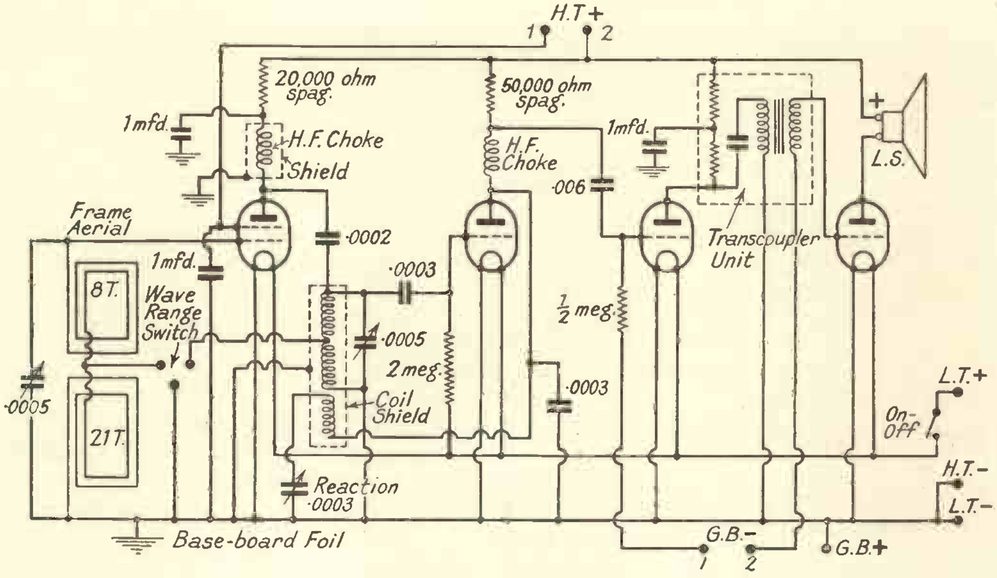


Fig. 17.—THEORETICAL CIRCUIT DIAGRAM.

A straightforward efficient circuit embodying the best modern features of pedestal receiver design.

circuits, the other is provided to enable the screen grid voltage to be regulated, probably a value of about 50 to 70 volts will be suitable. Check and test all the wiring, insert the set into the top compartment and screw it in place, fix the control knobs and dials and connect up the loud speaker.

Put the battery leads through the hollow legs, fit terminal tags and wander plugs as requisite, insert the valves and connect up the batteries.

Operation

To operate the set, close the circuit by the " on-off " switch, set the wave range switch for medium or long waves and turn both tuning knobs until a station is heard; carefully tune it in to maximum strength by independently adjusting them, and by turning the reaction condenser knob.

Note the readings, then try the effect of varying the output leads to the loud speaker transformer tappings, leaving them alone once the best tonal results have been obtained.

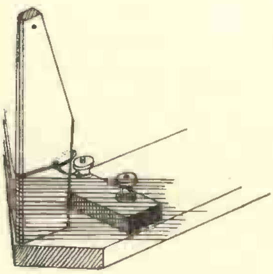


Fig. 18.—DETAIL OF WINDINGS AND TERMINALS.

Choice of Valves

There is nothing critical about the valves for this set, any ordinary screen-grid valve will do for the first stage; a fairly high impedance valve for the detector stage, say, 22,500 ohms; a medium impedance valve of about 20,000 ohms in the first L.F. stage and a standard power valve with impedance of about 3,600 ohms in the last stage.

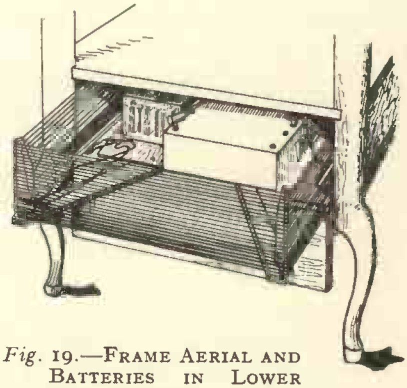


Fig. 19.—FRAME AERIAL AND BATTERIES IN LOWER COMPARTMENT.

PRACTICAL WIRELESS SET CONSTRUCTION

By H. E. J. BUTLER

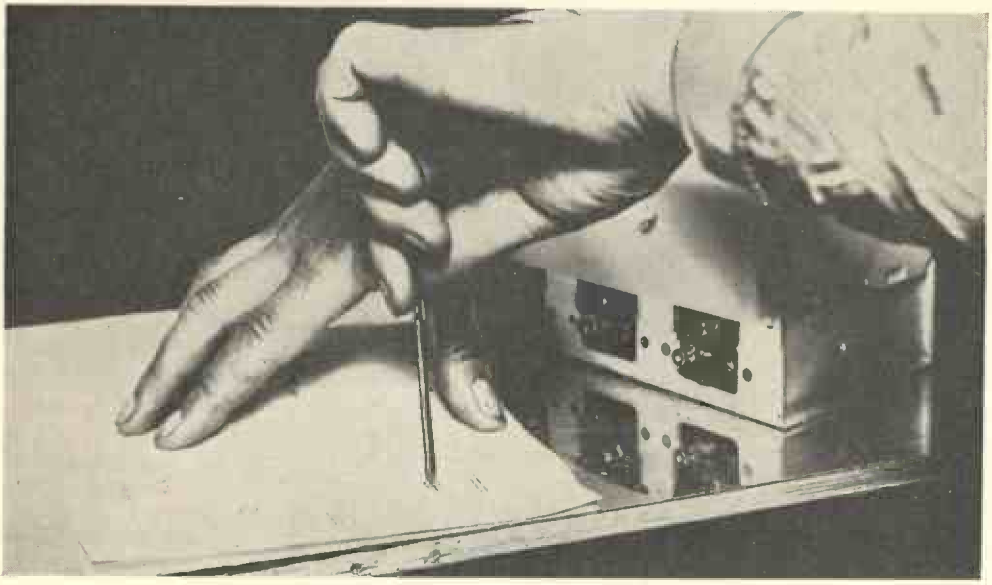


Fig. 1.—Marking off the Fixing Holes for a British Radiophone 3-gang Condenser. This is done with the aid of a paper template.

THE construction of wireless receivers and gramophones with valve amplifiers is a subject which appeals to all radio enthusiasts, because very few tools are necessary, and none of the processes involved calls for great skill.

BASEBOARD ASSEMBLY

Tools Required

The necessary tools are screwdrivers, hand drill with twist drills from $\frac{1}{16}$ to $\frac{1}{4}$ inch, a scriber made from $\frac{1}{8}$-inch diameter silver steel, cutting pliers, and round-nosed pliers (4 inch). Sometimes a pad-saw or a fret-saw is necessary for cutting large holes in panels. A carpenter's brace and a variety of centre-bits considerably assist the drilling of the larger holes in the panel and baseboard. Centre-bits are preferable to twist-bits or augers, for the thin material which is used in the construction of wireless sets. Centre-bits may be used also to cut holes in thin soft metals, such as aluminium and copper, as well as for wood.

A Precaution

Before commencing the assembly of the parts on the baseboard, it is very desirable to test all the components separately. This procedure saves a great deal of fault-tracing in the finished set, because the location of one defective part in a large receiver may be difficult, and at least necessitate the removal of a good deal of the wiring in order to find it.

The subject of testing is dealt with in the article entitled "Simplified Testing of Wireless Components," pp. 31—37.

It is advisable to examine all components carefully for secure terminals, lock-nuts, bushes, etc., prior to assembly. Not only does this save time in assembly,

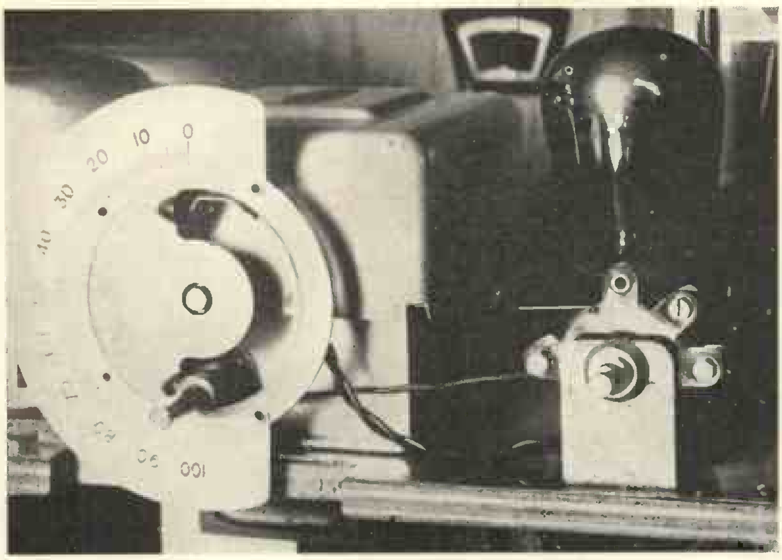


Fig. 2.—When a British Radiophone Condenser is mounted on the Baseboard without the Spacers it is Necessary to cut away a Portion to miss the Dial.

On the right is shown a reaction condenser mounted on a metal bracket. This form of construction is necessary when the panel is not fixed to the chassis.

but components which are faulty are more readily exchanged if they do not show signs of having been used in any way.

The Baseboard

The baseboard usually consists of a piece of ⅜-in. thick plywood or a specially shaped metal chassis. The baseboard may house all the components, sometimes a few are mounted on the panel. It is most convenient to fix all the parts on the baseboard when the panel is not fixed to it, because this arrangement permits the set to be withdrawn without disturbing the wiring to the control components. If the control panel and baseboard are fixed together it is better to mount certain control components on the panel, because it saves making special brackets for wave-change switches and rheostats.

Preparing the Baseboard

The first step in the preparation of the baseboard is to square it up. This assists in marking out the positions of the parts, and also improves the appearance. The edges of the baseboard are chamfered to make it more pleasant to handle when the set is finished. A finished chassis of an all-mains set is heavy, and the presence of splinters on the edges makes its handling very unpleasant.

Setting Out the Baseboard

The various holes for the components are marked out with the aid of a scriber or pencil, a rule and pair of dividers. A scriber is preferable to a pencil, because a more definite line or mark can be made than with a pencil. The largest components are placed first. The variable condenser or condensers are usually the largest parts. The latest pattern gang condensers are made for baseboard mounting.

A Note on Condenser Mounting

A point to remember when setting out for a baseboard-mounted condenser is that the driving spindle is not necessarily central with the body of the condenser, so that, if the tuning dial is to be in the middle of the panel, the spindle, and not the main body of the condenser, is set on the centre line of the panel.

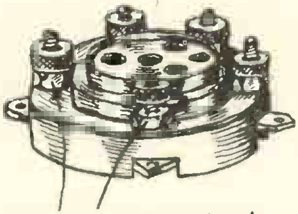


Fig. 3.—Examine all Components to make sure that Lock-nuts and Screws are Secure.

Templates and Their Use

Some manufacturers supply paper or tin templates for setting out the fixing holes of their components. Fig. 1 shows the paper template of a British Radiophone 3-gang condenser being used to mark the three fixing holes. The template is held flat or pinned on to the baseboard while a scriber is used to mark the centres of the holes through the paper. In order to space the condenser at its correct distance from the front edge of the baseboard, the template is first folded along the line on the template, representing the front edge of the condenser. Do not attempt to iron out the paper or wet it to make it lie flat, or the size of the template will be altered.

Using Components as Templates

Wherever possible, mark out the fixing holes from the components themselves, because they often vary even in the same make and type of component.

Large Baseboards

Large baseboards, which are not supported on four sides when placed in the cabinet, must have extra support or the board will sag, as shown in Fig. 6, and cause the spindles to bind on the holes in the

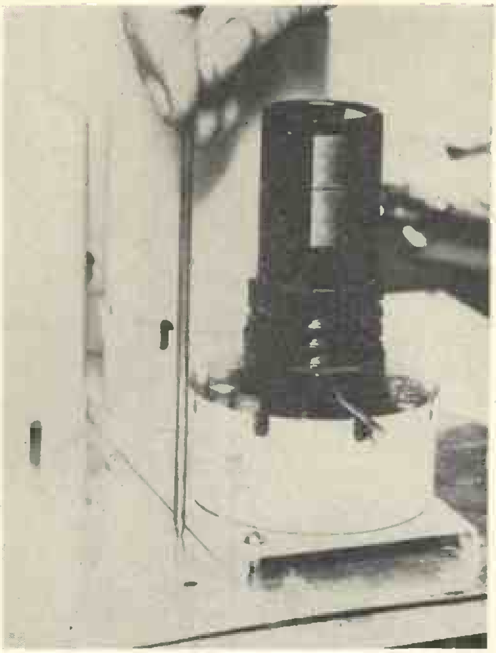


Fig. 4.—Marking off the Position of a Hole to Carry a Wire from a Tuning Coil to a Component below the Baseboard.

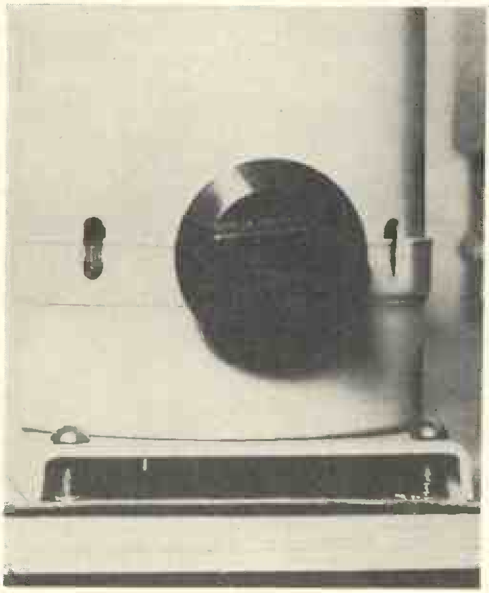


Fig. 5.—When Components are mounted on a Metal Screened Base take care to remove the Burrs from the Underneath of the Plate before fixing the Components, or they will not Seat Down Properly.

panel, besides leading to dangerous distortion of delicate components. This support may be a batten, say $1\frac{1}{2} \times \frac{3}{8}$ inch, screwed edgewise on the baseboard or a prop $1 \times \frac{3}{8}$ inch, placed between the underside of the board and the bottom of the cabinet.

Screened Baseboards

A suitable construction for all-mains receivers is to place the high-frequency components and valves above the baseboard, and the mains equipment and low-frequency gear below. When this form of construction is adopted the two assemblies of parts are screened from each other by covering the base with a sheet of aluminium or tin plate. The screen is put on the side with the least number of fixing holes, usually the top. Aluminium gives an electrostatic screen, while tin plate or tinned iron, which it really is, provides a magnetic shield. This plate is earthed, and consequently provides a convenient surface on which to make earth connections

Fig. 6.—PART OF A 2-VALVE ALL-MAINS RECEIVER.

Showing the sag in the baseboard caused by the weight of the components. This also shows a method of mounting the terminal block for the speakers on the side member of the chassis.

to the various components of the set. Fig. 11 shows an example of this. This convenience alone warrants a metal-covered baseboard to most types of receivers, because of the saving in wiring which is thereby effected.

Drilling the Baseboard

Although one may be accustomed to driving in wood screws without first drilling a suitably sized hole, this must not be done when fixing components to a ply-wood, or hardwood base, or screws will be broken in, which are not possible to remove. The table below gives the tapping sizes for small wood screws :—

Screw No.	Tapping Drill.	Clearing Drill.
1	No. 67, or $\frac{1}{32}$ in.	No. 50
2	No. 60	No. 42, or $\frac{3}{32}$ in.
3	No. 56, or $\frac{3}{64}$ in.	No. 40
4	No. 55	No. 32
5	No. 53, or $\frac{1}{16}$ in.	No. 30, or $\frac{1}{8}$ in.
6	No. 50	No. 28, or $\frac{9}{64}$ in.
7	No. 48, or $\frac{5}{64}$ in.	No. 22, or $\frac{5}{32}$ in.

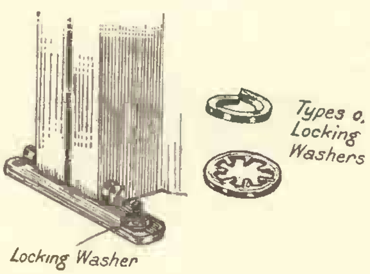


Fig. 7.—WHEN BOLTING HEAVY COMPONENTS TO PANELS IT IS WELL WORTH WHILE TO USE LOCK-WASHERS.

It does not matter if the screw holes are drilled right through the baseboard ; in fact, it is better to do so when components are to be mounted on both sides, so that the screws on the under side may be set out to miss those from the top.

Large Holes in Panels

It is frequently necessary to cut large openings in panels, for condenser escutcheons and milliampere metres. This is most efficiently accomplished by using a fretwork machine, or hand fretsaw if a machine is not available. Fig. 12 shows a machine in use cutting a 3-inch diameter hole for a meter. On the left of the photograph is the opening for the escutcheon of a British Radiophone condenser. Large round holes may also be cut with a fly-cutter, similar to a plumber's tank cutter, but great care is necessary when drilling thin plywood with these tools. A third method of cutting these holes is to use a pad-saw with an extra piece of wood clamped on the face side of the panel. The object of the extra thickness of wood is to prevent the face-ply from splintering round the hole. This is especially necessary when the plywood has a veneer facing of hardwood only a fraction of a millimeter in thickness.

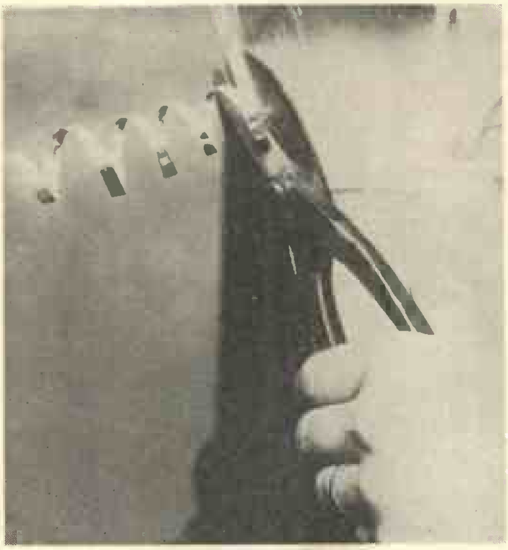


Fig. 8.—When cutting Sheet Metal always hold the Blade of the Snips, adjacent to the Body of the Metal, Flat on the Sheet whilst cutting.

This is done so that the waste and not the sheet buckles.

Fixing Heavy Components

Wood screws do not provide a safe method of fixing heavy components unless the baseboard is over ½ inch thick.

Mains transformers of multi-valve receivers and chokes of power amplifiers must be fixed with nuts and screws, which will generally be 4B.A. size. When 4B.A. nuts and screws are used, $\frac{5}{32}$-inch holes are drilled right through the baseboard. For 2B.A. screws, $\frac{7}{32}$-in. holes are drilled.

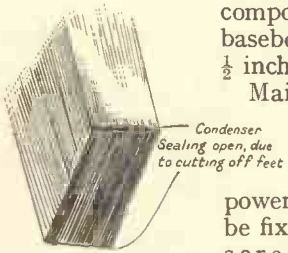


Fig. 9.—This shows what happens when the Fixing Feet of a Condenser are removed.

When bolting on components to panels, and in particular heavy components, it is well worth while to use locking washers. The washers may be used with advantage under terminals. Types of locking washers and how to use them are shown in Fig. 7.

Very Light Parts

Certain very light components, such as fixed condensers and fixed resistances, are designed so that they may be suspended on their own wiring, and thus do not require any space on the baseboard. Spaghetti resistances come in this class of component. These have terminal tags so that they take the place of the wiring which is necessary if base-mounted resistances are used. When mounting Spaghetti resistances be careful not to strain them by making sharp bends, particularly near the connecting tags, or the resistance may be damaged. Some components of this type are made with short stiff wire ends. Examples of these are Loewe vacuum resistances and condensers, and Erie resistances.

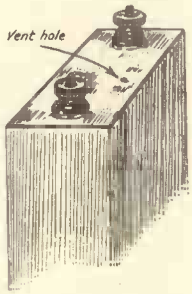


Fig. 10.—When mounting an Electrolytic Condenser see that the Vent Hole is at the Top.

Terminals of Components

Components are made with three kinds of terminal connections; screw terminals,

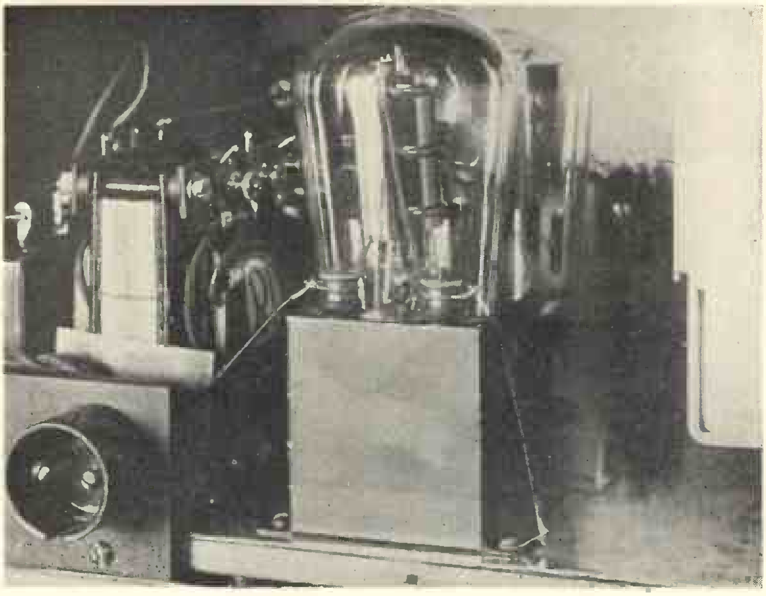


Fig. 11.—PART OF A 3-VALVE ALL-MAINS SET.

Showing the location of the mains safety plug at the rear of the receiver and the method of earthing one end of a fixed condenser to the metal base.

the type of instrument used by manufacturers, and is less suitable for amateur or experimental work, because the wires, once soldered to their respective points, cannot be removed easily for testing purposes. Parts with a combination of screw terminals and soldering tags are sometimes preferable to those which have only one kind of connection, since they permit several common wires to be joined neatly and easily.

soldering tags and flexible or stiff wire ends. Most parts available to the amateur constructor have screw terminals. A large number of parts now have both screw terminals and soldering tags. Mains transformers and chokes are made with flexible wire ends as an alternative to screw terminals or soldering tags. This is

Avoiding Interaction Effects

In receivers employing components possessing magnetic cores, such as loud speakers, mains and intervalve transformers, smoothing and output chokes, care must be exercised in the mounting of these components relative to each other and to the tuning coils. It may even be necessary to wire certain of these components with flexible wires and to orientate them until the position of least interaction (or hum) is found.

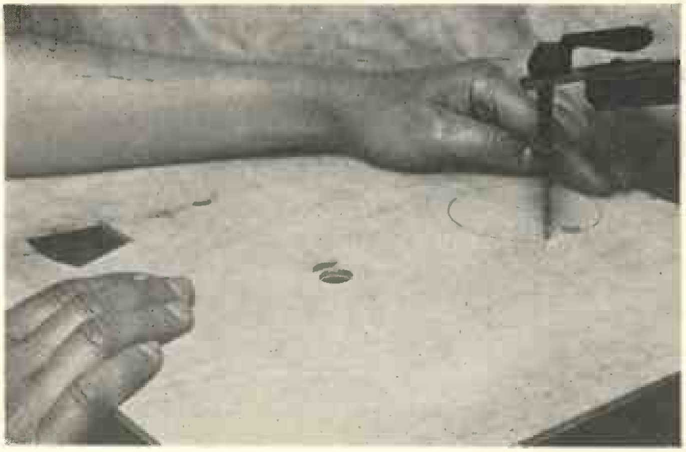


Fig. 12.—CUTTING LARGE HOLES IN THE PANEL WITH A FRETWORK MACHINE.

How to Mount Fixed Condensers

When mounting fixed condensers, care should be taken to ensure that nothing is done which will affect the "seal" of the condensers, otherwise breakdown may ensue at a later date.

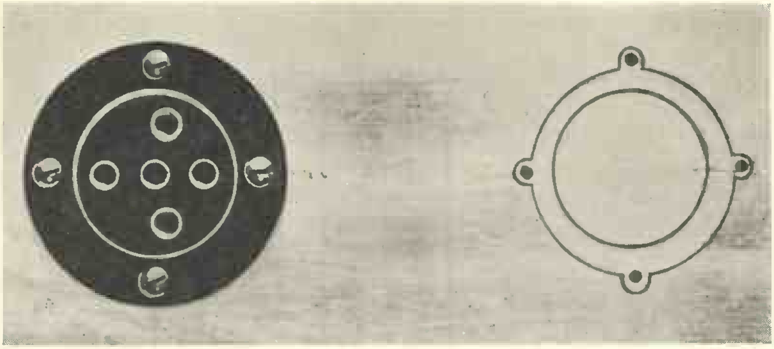


Fig. 13.—A CLIX CHASSIS-MOUNTING VALVE HOLDER.

Showing the method of giving extra clearance round the metal part of the baseboard.

Cutting off the fixing feet of metal-cased condensers, with the object of saving space when clamping a number together, is a sure way of breaking the seal either by exposing the interior through cutting too close or by straining the soldered joints so as to allow moisture to enter.

Fig. 9 shows a condenser in which the seal has been broken in the manner described.

Condensers having black sealing compound on the top should always be mounted vertically, otherwise heat may allow the compound to ooze out and break the seal.

Should the apparatus be intended for use in very warm, moist atmospheres, or out of doors, Tropical Filled Condensers are recommended. These can be obtained from most manufacturers.

Special Points Regarding Electrolytic Condensers

Examination of practically every form of electrolytic condenser will reveal a small vent hole (or holes).

It is important that the condenser should be so mounted that this vent is at the top. The vent is there to allow gas to escape when necessary, and, should the condenser ever become momentarily reversed and mounted other than vertical, there is a possibility of the electrolyte contents being discharged through the vent hole by gas pressure.

Further, if the condenser has a metal container, this is almost certain to be

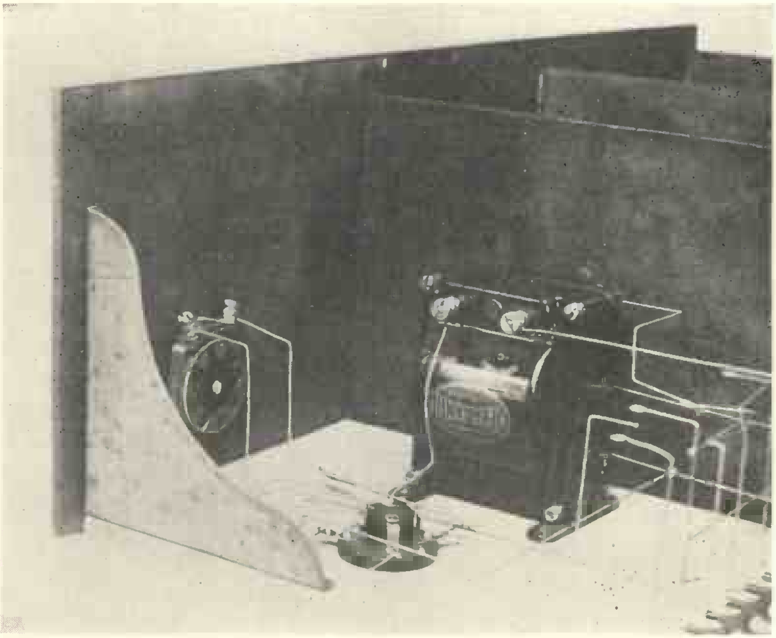


Fig. 14.—A PORTION OF A BATTERY RECEIVER SHOWING THE METHOD OF SECURING THE PANEL TO THE BASEBOARD BY MEANS OF A METAL BRACKET AND THE SCREENING BOXES.

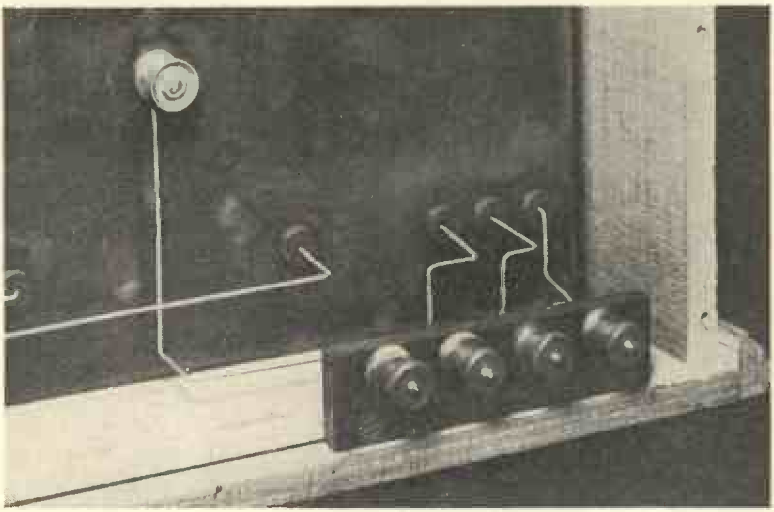


Fig. 15.—AERIAL TAPPING AND EARTH TERMINALS OF A RECEIVER.

Showing how the terminal block is mounted to project through the back, as shown in Fig. 16.

" alive," due to the electrolyte making contact with it, even though insulated terminals are provided. It is therefore advisable to always insulate the condenser from the chassis. A block of good dry hardwood is quite suitable providing the fixing screws of the condenser do not protrude. This does not apply to the circular type of condenser, in which the case itself is one electrode and the condenser is designed to be bolted direct to the chassis.

WIRING

Bare Wiring

A form of wiring, once in general use, is bare tinned 18 S.W.G. copper wiring, examples of which are shown in Figs. 14 and 15. This kind of wiring is best avoided, because it is unsafe, especially now that metal chassis, panels and screens are used. Bare wiring necessitates liberal spacing between the wires, which is not always convenient or desirable.

Sleeved Wiring

The second type of wiring consists of bare tinned 18 S.W.G. copper wires, insulated with Systoflex sleeving. This method of wiring is quick and neat, providing that the wire lengths are not complicated by many bends. Wires are distinguished from one another by the use of different colours of sleeving. The sleeving must not fit too loosely on the conductors, or the wiring will look untidy. For 18 S.W.G. wire, the correct size of sleeving is 1-mm. bore.

Insulated Wire

The kind of wire which gives the neatest appearance in the hands of a careful wireman is Glazite, or a similar proprietary article. This wire has a hard, glazed surface and the ends can be cleaned and soldered without causing the insulation to unravel. This wire is obtainable in several colours, which greatly assist the wiring of a large receiver. This wire should not be used for the high voltage

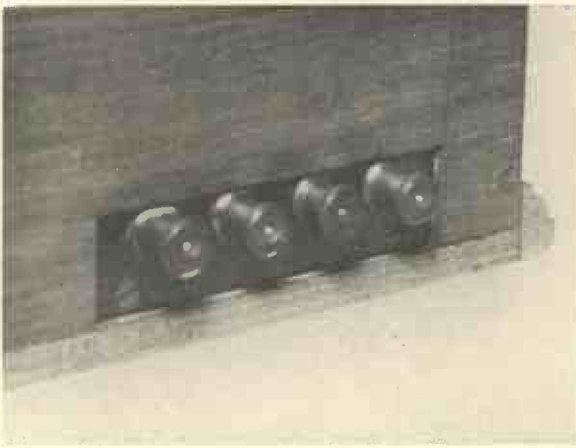


Fig. 16.—THE APPEARANCE OF THE TERMINAL BLOCK SHOWN IN FIG. 15 WHEN THE BACK IS SCREWED ON.

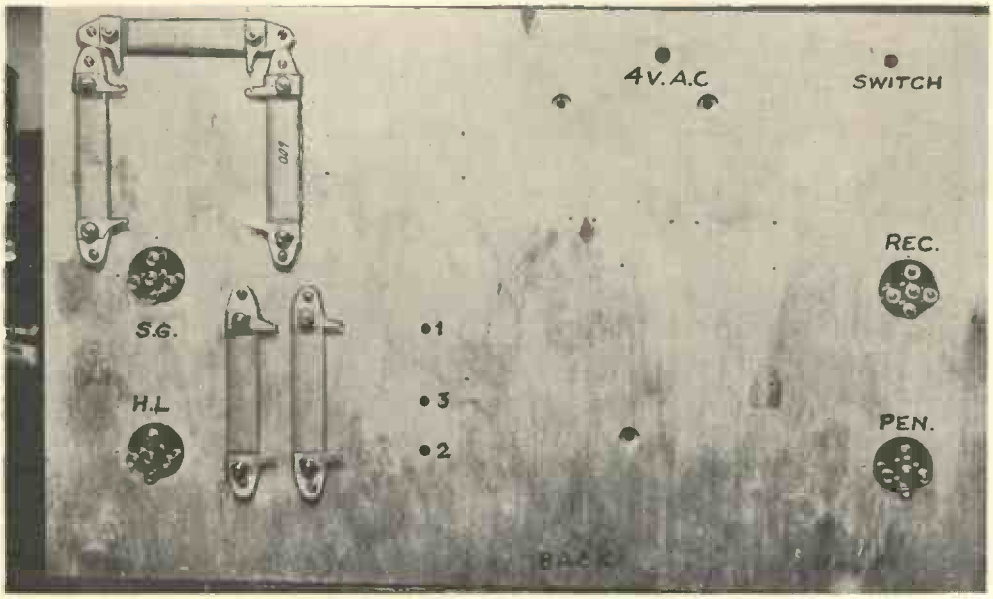


Fig. 17.—THE PARTLY-ASSEMBLED BASEBOARD OF A 3-VALVE ALL-MAINS RECEIVER.

Showing the first stage of the underneath construction after drilling all the holes. Note the method of marking the valve holders and holes for wires through the baseboard, to avoid confusion.

leads over 300 volts different from earth potential.

Rubber-Covered Wire

Rubber-covered flexible leads are used for A.C. leads from mains transformers. Flexible wire is preferable, because the pairs of leads have to be twisted to prevent interference. Rubber-covered 1/·036-inch solid conductor may be used in place of the flexible wire if desired. For high tension, twisted leads over 250 volts A.C. flex of lighting quality is avoided. The best material for this purpose is 5 mm. C.T.S. (cabtyre sheathed) flexible wire, which is the kind of cable used for the H.T. ignition leads of motor cars.

Screened Wiring

When it is unavoidable that A.C. leads run closely to valve grid leads, or are a considerable length, the usual method of preventing hum induction by the use of twisted leads may be insufficient. Similarly, when the leads from a gramophone pick-up are long, the wiring must be electrostatically screened. There are two ways of screening the wiring when either of these conditions arise. The first method is to use metal braided sleeving, and the second is to use lead-covered wire. Twin lead-covered cable is the best to use for A.C. leads, especially those to the gramophone motor and from the mains input plug to the transformer primary. Metal-braided sleeving is more suitable for pick-up leads, because these generally hang in mid-air for a foot or so. The use of lead-covered cable is to be avoided, unless it can be supported along its entire length.

The metal sheathing of all screened leads must be earthed to be effective.

Methods of Wiring

There are two distinct methods of arranging the wire connections between the various components. The first, to keep all the wire horizontal and vertical with right-angled bends. This method is very neat if accurately done, but is more difficult than the other way, and necessitates longer leads than direct wiring. This kind is, therefore, to be avoided.

The other method of wiring, direct wiring, is to keep the leads as direct and short as possible, having due regard to the proximity of wires which are liable to interact.

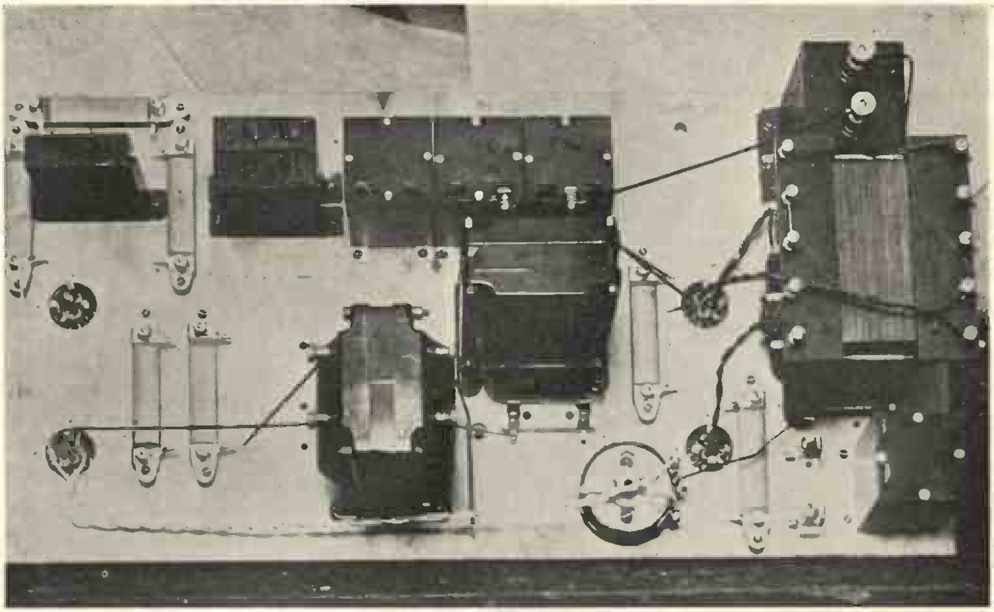


Fig. 18.—The Underside of the Baseboard shown in Fig. 17 with the First Stage of the Wiring, *i.e.*, Screw Terminal Connections, completed.

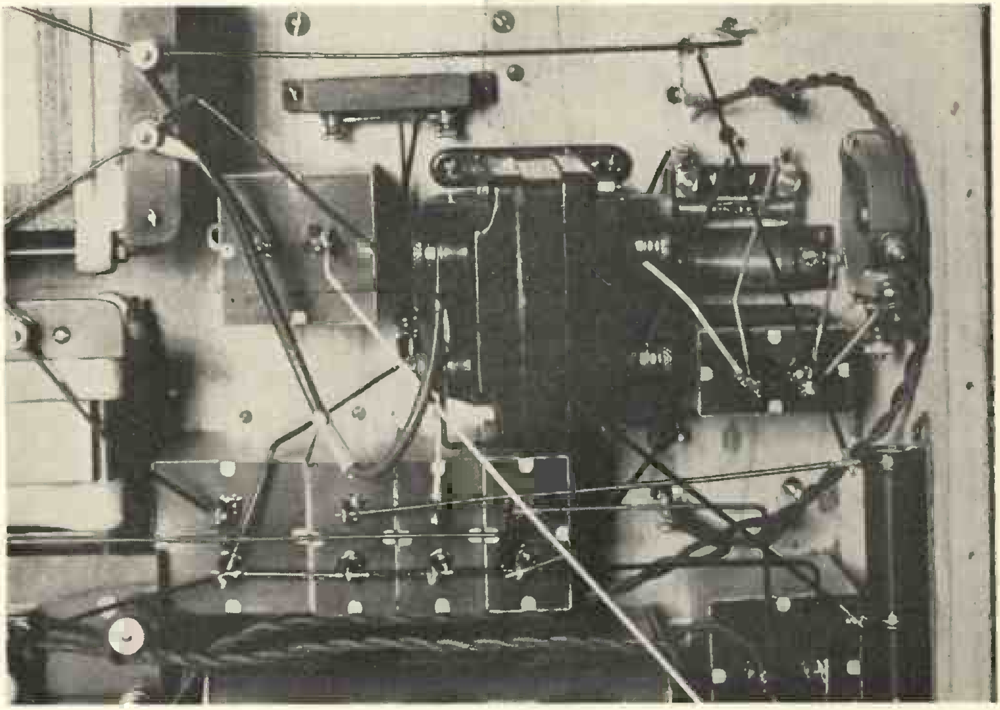


Fig. 19.—A Portion of the Mains Components of a 2-Valve Receiver to show the Method of Wiring.

Note the components mounted on the vertical member of the chassis.

However the wiring is done, the leads are kept straight with sharp bends, not necessarily right-angled bends. The use of curves in the wiring is unsightly. An example of direct wiring is shown in Fig. 19.

The use of flexible wire is avoided wherever stiff wire can be used instead, since flexible leads will not maintain a definite shape, and are, therefore, detrimental to the appearance of the wiring.

Where long wires carrying H.F. currents are employed, it is sometimes an advantage to increase the gauge of wire for rigidity—provided the self capacity is not unduly increased due to its proximity to the chassis. Vibration on a long wire will sometimes cause weird and unwanted effects.

When using a metal chassis, keep the wires going to the valve grid and anodes away from the metal to avoid capacity effects.

Cutting the Wires

The first operation in preparing the wires is to cut them to length. The wiring must be done step by step. Do not attempt to cut and fix more than six leads at a time, or confusion will result. The wire is cut with a pair of cutting pliers, specially kept for soft wire. If insulated wire, such as Glazite, is being used, make sure that the cutting pliers are in good condition. Much time will be wasted if the pliers do not cut properly through the soft insulation. The length of each lead is estimated as nearly as possible before cutting it from the hank. When the path of the wire is somewhat inaccessible, this is done with a piece of flexible wire or thread. When wiring to screw terminals, an extra ½ inch is allowed for the loop round the screw. Remember that it is better to cut a lead a little longer than necessary rather than have to waste the whole wire.

Straightening the Wire

The next process, which is necessary for all leads except the shortest, is to straighten the wire after cutting. The presence of kinks and irregular curves in the wiring gives a slovenly appearance to the job. Straightening is done as shown in Fig. 20. After cleaning both ends of a wire, one end is clamped in the vice and the other in a strong pair of pliers. The wire is then pulled until it stretches, when it will be found to be perfectly straight.

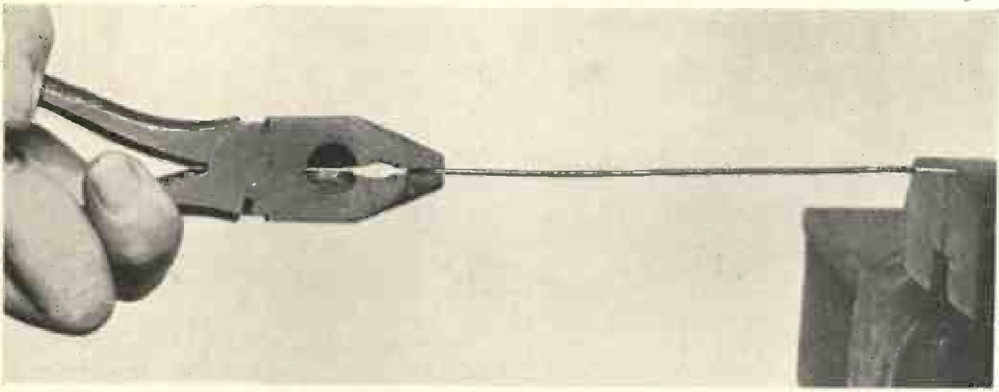


Fig. 20.—Stretching a Wire to remove the Kinks and Bends.

Do not stretch the wire more than a fraction of an inch, because it may break or crack the insulation. This expedient may be used when it is found that a wire has been cut just too short, especially if the lead is a long one. It is necessary to roughly straighten out the wire before stretching if it has been bent to shape.

Cleaning Wire Ends

The ends of insulated wire can be cleaned in one of two ways. One method is to use a sharp knife. The knife is run round the insulation until it just cuts right through, and the short piece of insulation is pulled off. Care must be taken not to nick the wire itself, or the end may break off if it has, subsequently, to be bent.

A more expeditious method of cleaning wire ends is to use the cutting pliers. The type of cutting pliers to use for this are top cutters, not side cutters. The wire is twisted round while light pressure is maintained on the cutters until the insulation is cut through all round and then the superfluous covering is pulled off. A little practice will enable this operation to be performed quickly and without nicking the wire.

Fig. 21.—Forming a Loop, with Round-nosed Pliers, for Screw Terminal Connections.

Cleaning Lead-covered Wire

Lead-covered wire is also cleaned of its insulation by the use of cutting pliers. The lead sheathing is removed first by nicking the lead about half way through and then breaking it off. When cleaning the ends of lead-covered cable always remove at least an inch more lead than rubber, so as to ensure that the connecting point cannot make contact with the conducting sheath, which is earthed. When the lead is removed the cotton tape is unwound and cut off and then the required amount of rubber insulation is removed with the cutting pliers, in the same way as for ordinary insulation, just described.

Wire Loops for Terminals

To ensure a good contact under screw terminals, the wire ends must be formed into closed loops before they are put on to the screws. These loops are formed with a pair of round-nosed pliers, as shown in Fig. 21. The ends of the pliers are tapered so that any required size of loop can be formed with one twist of the pliers. The loops are made to fit the screws closely, but must slide on freely. The wire must be bent round the same way as the direction of screwing up of the terminal head, so that the loop tends to close up when the terminal is tightened. If the loops are wound opposite to the threads they will splay out when the terminal is done up.

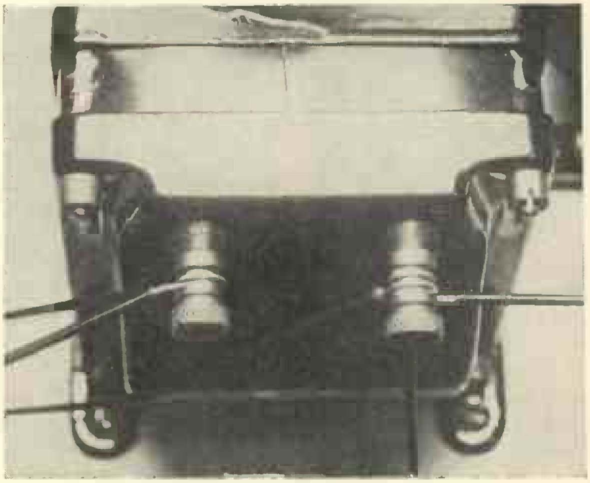


Fig. 22.—How Several Wire Loops are satisfactorily accommodated on a Single Terminal by the use of Washers.

Fig. 22 shows how several wire loops are accommodated when it is necessary to clamp several under one terminal. Washers are placed between each loop to prevent them from opening out when tightened up. The washers should be the thick, turned variety

BROADCASTING HOUSE

AN ILLUSTRATED DESCRIPTION

Undoubtedly one of the most fascinating buildings in England, Broadcasting House has now been fittingly described and illustrated in the official Description issued by The British Broadcasting Corporation. Finely printed, and bound in an exceedingly attractive gold-blocked orange cloth, this book contains a Detailed Description of thirty pages; four reproductions of photographs, printed in colour; thirteen floor plans in colour, showing the lay-out of the studios on each floor; and ninety-eight monochrome illustrations. The size is 10 in. by 7½ in. It is one of the finest books ever issued at the price; and it can be obtained from all booksellers, newsagents and bookstalls, price five shillings, or direct from the B.B.C. (Publications Dept.), Broadcasting House, London, W1, 5s. 9d. post paid.

This article on "Practical Wireless Set Construction" is continued in Part 3. Ready September 30th. Order your copy to-day.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia : GORDON & GOTCH (Australasia) LTD. South Africa : CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

CONTAINING

CHART TO MAKE "PRE-TUNED THREE"

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

SERVICING PYE RECEIVERS

1/-

Part 3

IN ABOUT 24 WEEKLY PARTS


IN THE HANDS
OF RADIO EXPERTS
LEWCOS
RADIO PRODUCTS
CHOKE
The leading electric wire manufacturers for over 50 years, Lewcos have been in the van of Radio progress from the commencement. Lewcos Components are indispensable for perfect reception.
Write for leaflets with these reference numbers :
COMPONENTS OF EVERY DESCRIPTION
L.F. and H.F. Transformers - - - Ref. Nos. N76.
L.F. and H.F. Chokes - - - - ,, ,, N76 & 78.
Potentiometers - - - - - ,, ,, N79 & 81.
Band Pass Filters - - - - - ,, ,, N73a.
Spaghetti Resistances - - - - ,, ,, N78.
Glazite Connecting Wire. Silk and Covered Wires.
Lewcos
REGD
LEWCOS RADIO PRODUCTS FOR BETTER RECEPTION
THE LONDON ELECTRIC WIRE COMPANY AND SMITHS LIMITED, CHURCH ROAD, LEYTON, LONDON, E.10.

and not the thin stamped ones, to ensure a flat seating for each loop.

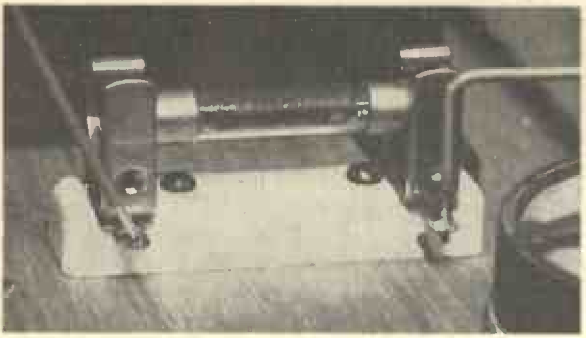


Fig. 23.—THE WIRING OF A HIGH-RESISTANCE LEAK HOLDER TO SHOW THE SIMPLEST WAY OF SOLDERING WIRES TO TAGS.

Bending Wires

The wires must not be bent sharply at the corners. If bare wire is bent sharply, it is difficult to thread on the sleeving, and if insulated wire is sharply bent the insulation cracks. Bending, therefore, is done with round-nosed pliers and not with flat ones.

Braided Flex

When braided flex is used, the ends of the braiding are bound with cotton or thread, to prevent it from fraying out. Whenever possible, it is better to remove the braiding altogether, or to use plain rubber-covered flex, since the braiding contributes practically nothing to the insulation, and binding the ends is a tiresome operation. The ends of braided flex may, however, be quickly cemented together by using Rawplug's Durofix.

SOLDERING

Soldering and Terminals

Although most components are available with screw-terminal connections, it is not advisable to construct a wireless set with any screw connections which can be avoided. Even when terminals or screws must be used, it is safer to clamp a soldering tag under the terminal and then to solder the wire to the tag. When screw terminals are used, with or without soldering tags, it is not sufficient to leave the terminals finger tight; they must be carefully tightened with the pliers, or sufficient corrosion may take place to lower the efficiency of the joint.

Joints are the weakest parts of an electrical circuit, and too much care cannot be exercised when making them.

Soldering Bit

The soldering bit should weigh from ½ to ¾ lb. The use of a bit of less than ½ lb. makes the soldering more difficult, because the bit loses its heat too rapidly and has to be made much hotter than necessary to secure good joints on a number of connections. A soldering bit heavier than ¾ lb. would be an advantage, except that it is cumbersome, and is thus difficult to manipulate between the components and wires.

The best section, for the soldering bit, is rectangular, because a rectangular bit may be heavy and yet be made thin enough to pass between the narrow spaces when wiring up.

Before Soldering

Before soldering is commenced, it is a good plan to tin all the soldering tags of the components. It may be found that some of the soldering tags or terminals are nickel-plated. The nickel must be filed or scraped off before the application of solder.

Tinning consists of covering a surface with a thin layer of solder. This is done with the soldering bit. The surface to be tinned must be perfectly clean. The simplest way to ensure this is to give the surface a few rubs with a smooth file.

All the wire used should be purchased already tinned. The special insulated wires produced expressly for this kind of wiring are tinned. Sometimes flex has to be tinned. This is a little more difficult to tin than a single wire, because all the strands have to be clean before the solder takes properly.

Soldering Flux

The only safe fluxes to use are tallow and resin. Tallow is used only for making connections to the lead covering of cables for earthing. Resin is the flux used for wiring. When all the connections are freshly tinned, resin-cored solder is used without any extra flux.

If plain solder is used for jointing and tinning, resin is used. This is best applied as a solution in methylated spirits, because the powdered form is difficult to apply on small joints.

Never use soldering spirits or any patent soldering preparation for wiring.

How to Solder

The two main points to observe when soldering are cleanliness and the temperature of the soldering bit. If all the joints are freshly tinned, and the solder is firmly adhered, no trouble will be experienced from dirt. The chief cause of difficulty in soldering is the incorrect temperature of the copper bit. The soldering bit itself must be free from dirt and kept well tinned.

Do not heat a soldering bit in a fire if it can be avoided. If a fire is the only means of heating the bit, wait until the fire is clear, or better still, make a fire of coke or Coalite.

To judge the temperature of the hot copper bit watch the colour of the molten solder on the bit. When it turns colour after the solder has been wiped with a rag, it is hot enough. The more practised user judges the temperature by holding the bit a few inches from his cheek.

Always wipe the tinned surface of the soldering bit after removing it from the flame. Do not allow the flame to impinge on the tinned surface; but heat it just above this.

When making a joint with cored solder, a little of the solder is first melted above the joint and the resin allowed to drop on to the surfaces to be soldered, while the solder is taken by the bit. The cored solder is then withdrawn and the bit applied to the work when the solder runs from the bit to the joint. When plain solder is used, some resin solution is run in the joint first, then after applying some solder to the bit, it is transferred to the joint by the heated bit.

Kinds of Joints

There are several ways of soldering wires to their tags. One method is to lay the wire end flat along the tag. This is a good method because it makes a neat joint and gives plenty of surface along which to solder.

The second way, shown in Fig. 23, is to solder the wire while it is held in the hole of the soldering tag. This joint is not so good as the first method, but is safe and frequently more convenient. This method can be improved if the wire, after passing through the hole in the tag, is bent once round the tag. A very good type of joint is made when a wire is soldered into a slot. This kind of joint is used for the set terminals and valve sockets below the baseboard.

Testing Soldered Joints

When the joints have been soldered they are tested to verify their strength. If any of the joints have not run properly a light pull or twist on a wire will break it away from its tag. Although a joint may look perfect, the wire may be stuck only by the resin flux on account of dirt or movement of the wire at the moment of the setting of the solder.

MATCHING LOUD SPEAKER IMPEDANCE

WHEN an old set is being modernised and a new loud speaker is being incorporated, the first thing is to get the impedance of the loud speaker matched up with that of the last valve. Good results are obtained when the impedance of the loud speaker is about twice that of the last valve at a frequency near the middle of the most important range, say about 300 cycles per second. If necessary add an output transformer with a multiple switching arrangement and adjust it by ear until the most gratifying results are obtained.

Should the addition of a screen-grid stage, or a push-pull amplifier be contemplated, it will generally be advisable to scrap the old set and rebuild it entirely, incorporating such new parts as are needed, and only making use of such of the original components as are perfectly suited to the purpose.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION III—ELECTRICITY AND MATTER

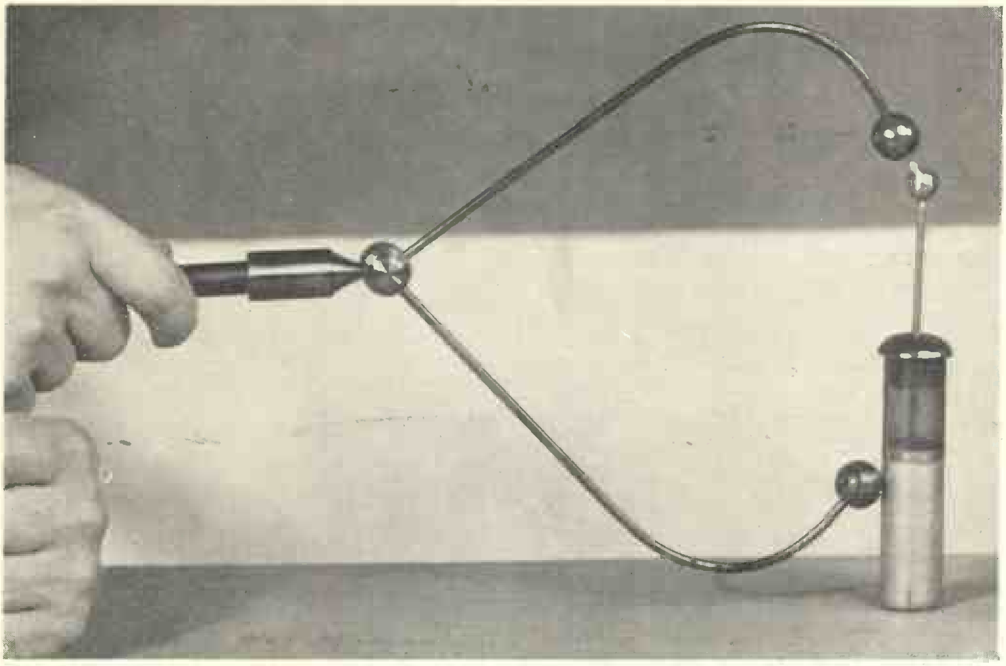


Fig. 1.—DISCHARGING A LEYDEN JAR.

A glass jar lined with tinfoil inside and outside can be used to store electricity as explained in the previous article in this series. Here we see such a jar being discharged. Note the spark passing between the upper knobs.

IN the preceding sections we have seen how an electric current can be produced and some of the things it will do. We have also seen how "static" electricity can be produced by friction and how it can be detected by the electroscope, and stored in a Leyden jar or condenser.

Before proceeding further on the practical side, we will now take a broad view of the modern theory of electricity. For the moment this may seem remote from the study of wireless, but it will be found of immense advantage later. If you were building a high structure you would start with a broad and solid foundation. The same applies to the building up of a knowledge of wireless theory.

The Ninety-two Elements

In everyday life we come into contact with a large number of substances such as bread, wood, paper, salt, wine, glass, bricks, etc. If one were to dissect all such substances and count the number of elementary materials of which all these substances are made, he would discover that there are only *ninety-two* such elements. The chemist calls these elementary materials *chemical elements*. The most familiar chemical elements to us are metals such as gold, silver, iron, lead, tin, cobalt, mercury, copper, etc. We also know of the gaseous elements such as oxygen, hydrogen, nitrogen, helium, etc. Other chemical elements such as sulphur, selenium, arsenic, iodine, etc., are also very familiar.

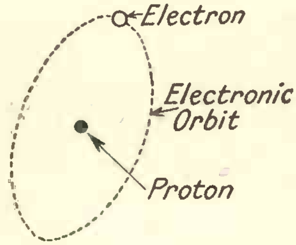


Fig. 2.—An Atom of Hydrogen.

Atomic Numbers

There are tables * giving a complete list of these chemical elements, arranged in the increasing order of weight. The table begins with the lightest element, hydrogen, and finishes with the heaviest element, uranium. The elements thus arranged, are numbered off from one to ninety-two, and these numbers are known as the *atomic numbers* of the elements.

Atomic Weights

Since hydrogen is the lightest chemical element, its weight is taken as a standard, and has been called 1. All other elements are taken to be so many times heavier than hydrogen, particle for particle, and in this manner we have another lot of numbers, indicating the *comparative* weights of chemical elements. These comparative weights are called *atomic weights*. Thus, if hydrogen is 1, oxygen is 16 times heavier, sodium is 23 times heavier, copper is 63·57 times heavier, and so on. It is clear, therefore, that each chemical element is identified first by its atomic number and then by its atomic weight. The significance of this will be evident from the next few paragraphs.

Meaning of the Word Atomic

If we take a quantity of water and start dividing it into smaller and smaller quantities we shall arrive in the end to very fine drops. Let us take a single drop and imagine that we have suitable instruments for dividing it still further as well as a very powerful microscope, enabling us to see the result of our labour. After a time we should arrive at a very small particle of water. On further division we would discover that the particle of water has disappeared and its place has been taken by three still smaller particles, particles which are not water but gases.

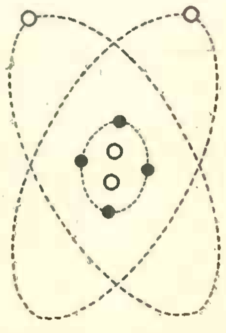


Fig. 3.—A Normal Atom of Helium.

Splitting Water into Gases

Thus, we would find that we have managed to split a particle of water into gases, to be precise, into two particles of the gas hydrogen and one particle of the gas oxygen. Water is a composite substance made up of these two gases (chemical elements) combined in a definite proportion. The smallest portion of water that on splitting loses its original character and for that matter, the smallest portion of any substance behaving in this manner, is called a *molecule* of the substance in question. The still smaller particles into which the molecule is split are called *atoms* (of chemical elements).

Molecules

A molecule of water consists of 3 atoms : 2 atoms of hydrogen and 1 atom of oxygen. Similarly a molecule of ordinary table salt consists of 1 atom of sodium and 1 atom of chlorine.

Every composite substance can be divided into molecules, the molecule being the smallest portion of the substance in question still keeping its characteristic properties. When the molecule is split, these properties disappear, and the atoms of chemical elements of which the molecule is made up, make their appearance.

Since the number of atoms that make up molecules differs, the size of a molecule will differ, but taking the average size of a molecule we should require 125,000,000 molecules side by side to cover an inch length ! In a small pin's head there are about 20,000,000,000,000 molecules.

The atom is smaller still. Four hundred million atoms

* See "Outline of Wireless" by Ralph Stranger [Newnes 5/6].

of helium would be required to cover an inch length.

To return to our table of chemical elements. As we already know, each element is identified by its atomic number (atomic numbers identify atoms of various chemical elements in the table just as house numbers identify each house in the street) and its atomic weight, this weight being not the actual weight of the atoms, but their comparative weight as compared with an atom of hydrogen.

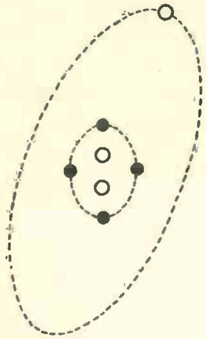


Fig. 4.—A Positively Charged Atom of Helium (one Electron lost).

How Elements are Identified by Symbols

In addition to this each element is denoted by one or two letters of the alphabet, so that each element has a *symbol* of its own. Thus hydrogen is denoted by H, oxygen by O, sodium Na, chlorine Cl and sulphur S. In using such chemical symbols, if we want to denote the composition of a molecule of water we write H_2O, the small figure 2 at the foot of H denoting the number of atoms of hydrogen present in the molecule of water. Sulphuric acid, which is made up of water and sulphur, has a molecule consisting of 2 atoms of hydrogen, 1 atom of sulphur, and 4 atoms of oxygen which is denoted as H_2SO_4. You will notice that when there is only 1 atom, the 1 is omitted at the foot of the letter. With such notation one can see at a glance how a molecule of a substance is made up.

What Happens within the Molecule

The atoms in a molecule are not packed closely together, they are at tiny distances from each other, vibrating to and fro, so do not imagine that a molecule is a hard little ball. There is more empty space within the boundaries of a molecule than atoms. If you imagine the boundaries of a molecule being the football field and the atoms being the two teams, you will get a fairly correct idea of what is happening within the molecule. No player can go, normally, outside the field, but he can be all over the place within the allotted area of action.

Molecules and their Effect on Temperature

The molecules as wholes are far from being closely packed within a lump of matter. They vibrate to and fro at small distances from each other. If a body is heated the molecules will vibrate faster and if the body is cooled the molecules will slow down. Thus what we call *temperature* of a body is merely *the rate of vibration* of molecules. The amount of heat possessed by a body is the amount of total molecular energy. (Heat is a form of energy.) It should be realised straight away that heat is a purely molecular property representing the sum total of the energies possessed by the molecules. Thus, it is absurd to talk about the heat or the temperature of interplanetary space. The space between the stars, if it is devoid of all matter, cannot have any heat or temperature.

Why Atoms and Molecules do not come Close Together

The reason why atoms and molecules do not come close together lies in the fact that there are forces acting between the atoms and the molecules which, on one hand, keep them within a certain distance from each other and, on the other hand, do not allow them to come too close together. The nature of these forces will become apparent as you proceed with your reading.

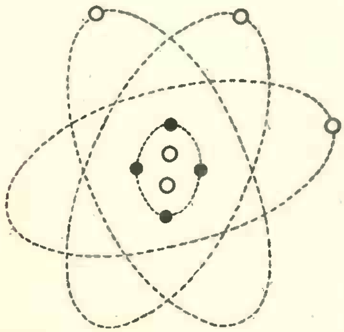


Fig. 5.—A Negatively Charged Atom of Helium (one Electron gained).

From Ice to Steam

Let us take a piece of ice. It is a comparatively hard substance which requires a good deal of force if it is to be broken up. The molecules of ice are, comparatively, strongly held together.

If we heat the ice we accelerate the motion of the molecules, they start to vibrate quicker and can go away from each other a little more than before. The cohesive forces between the molecules are thus weakened and the ice starts to melt, *i.e.*, becomes water. The cohesion of molecules of water is much weaker than that of ice, and we must have a vessel to keep the water from spreading. If we carry on heating the water we shall weaken still further the cohesive forces between the molecules, their rate of vibration and the distance through which they vibrate to and fro will increase so that water will begin to evaporate and will turn into steam.

The steam molecules are so energetic that they dart to and fro at great speeds, collide, shoot off at an angle so that if the steam is enclosed in a vessel, such as a steam boiler, the molecules will be constantly hammering away on the walls of the boiler producing what we know as steam pressure. As is well known, this steam pressure is a formidable affair, sometimes the boiler, although it is built very strongly, explodes when the steam pressure is too great. This should enable you to judge the magnitude of the aggregate molecular energy under certain conditions.

Cohesive Forces between the Molecules

It is clear by now that our apparently solid houses, solid bridges and other structures are not as solid as they appear. Their solidity is due to the cohesive forces between the molecules, but, nevertheless, they are masses of seething particles always in motion, always vibrating, the rate of vibration increasing with the increase of temperature and decreasing with its decrease. But tiny as the molecule is, its energy and its influence on other molecules is not to be despised. These energies and these forces add up so that they can hold together such structures as the St. Paul's Cathedral, our bridges, our engines and even our own bodies.

And at the bottom of it all is *electricity !*

What a Magnified Atom would Look Like

If an atom could be magnified so that its interior could be clearly seen by human eyes, it would prove to be a system very closely resembling the solar system. In the centre of the atom is a *nucleus* of two kinds of particles (an atom of hydrogen represents the only exception to this rule and has only one particle in the nucleus) while around this nucleus a number of particles is rotating just as planets rotate around the sun. The nucleus and each of the rotating particles are spinning around themselves. On closer inspection we should find that there are in the atom only two kinds of particles *in equal numbers*. One kind is smaller than the other kind. The smaller particles are all in the nucleus, while the larger particles are found both inside the nucleus and are rotating outside.

Electrons and Protons

These latter particles are called *electrons*. The smaller particles are called *protons*. The proton is about 1,845 times heavier than an electron. But the electron is about 1,870 times larger than the proton. It appears that practically the whole of the atomic weight is due to the protons.

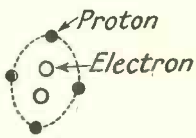


Fig. 6.—AN ALPHA PARTICLE.

Thus, *the atom of each chemical element consists of an equal number of electrons and protons*. All the protons and some of the electrons are in the nucleus of the atom, while the remaining electrons are playing the *rôle* of tiny planets and are rotating around the nucleus, each electron having a path of its own.

What Electrons and Protons are

Both the electron and the proton are particles of *pure electricity* (whatever this may be), but they appear to be particles of different kinds of electricity. The text books call the electricity due to protons *positive electricity*, and the electricity due to electrons *negative electricity*.* The words positive and negative have no special meaning and are used merely to indicate that the two particles are of a different kind. The amount of electricity or the *quantity* of electricity contained in each particle is the same.

* These names were given before the existence of electrons and protons was known.

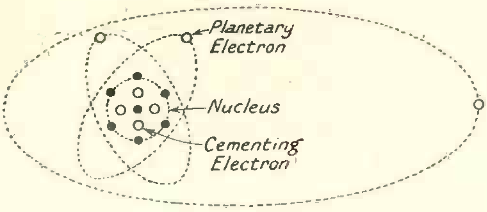


Fig. 7.—A Normal Atom of Lithium.

Thus, to sum up: *an atom consists of equal numbers of electrons and protons. An electron is* 1,870 *times larger than the proton, but the proton, although it is smaller, is* 1,845 *times heavier than the electron.*

Repulsion of Electrons and Protons

Electrons *repel* electrons. Protons *repel* protons. But a proton will *attract* an electron. These repulsive forces between like particles and the attractive forces between the unlike particles are responsible for the cohesion of matter. Take, in the first instance, the atomic nucleus. Protons by themselves could not exist as a nucleus, as they are repelling each other. For this reason they are "cemented" by a number of electrons. The remaining or "planetary" electrons are rotating in their paths or as we call them *orbits*, under the influence of the attraction of the nuclear protons and are kept at a distance from the nucleus and do not fall upon it owing to the repulsion of the nuclear cementing electrons and the *centrifugal force* produced by the rotation, the same force which keeps the planets from falling upon the sun.

Number of Protons in an Atom Equals the Atomic Weight

It has been discovered that the number of protons in an atom is always equal to the atomic weight of the element (in round numbers). The reason for this is that the atomic weight is only a comparative weight with an atom of hydrogen taken as unity. Since an atom of hydrogen has only 1 proton, as already mentioned, every other atom has as many protons as many times its weight exceeds that of a hydrogen atom. Since in every atom there are as many protons as there are electrons, the atomic weight also indicates the total number of electrons in the atom.

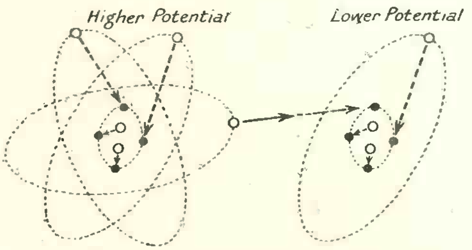


Fig. 8.—Planetary Electrons Travel from an Atom with a Greater Number of Electrons to an Atom with Fewer Electrons.

How to Find the Number of Cementing Electrons

The atomic number corresponds to the number of planetary electrons. Therefore, in order to find the number of cementing electrons in the nucleus, all we have to do is subtract from the atomic weight the atomic number of the element.

Hydrogen

The atomic number of hydrogen is 1, its atomic weight is also taken as 1. This proved to be a very good guess, as an atom of hydrogen has 1 proton in the nucleus (there are no cementing electrons, as they are unnecessary in the case of a single proton) and 1 electron rotating around the nuclear proton.

Helium

An atom of helium has an atomic number of 2 and an atomic weight of 4. Thus, we can say at once that it has four protons in the nucleus and it also has four electrons. The atomic number indicates that there are two planetary electrons, hence there must be also two cementing electrons.

Lithium

An atom of lithium has an atomic weight of 6·94, which is nearly 7. Its atomic number is 3. Hence, an atom of lithium has 7 protons in the nucleus. Of its 7 electrons, 3 are planetary and the remaining 4 are cementing the protons in the nucleus.

Uranium

Now let us take the heaviest element known, which comes last in our chemical elements table — uranium. The atomic number of uranium is 92. Its atomic weight is 238·2. It has 238 protons and 238 electrons in its atom. There are 92 planetary electrons and 238 protons and 146 electrons in the nucleus. As you see, an atom can be a very complicated structure. Its size (the size of its boundaries) must vary considerably with the number of protons and electrons present.

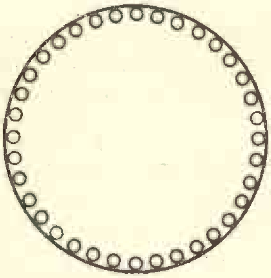


Fig. 9.—Surplus Electrons distribute themselves on the Surface of a Conductor.

The atom of one chemical element differs from the atom of another chemical element by the number of electrons and protons inside the atom.

Transforming One Element into Another

Thus, if we can change artificially the number of electrons and protons in the atom we can transform one element into another. It should be mentioned that the protons, under normal conditions, cannot be shifted from the nucleus. The same applies to the cementing electrons. The planetary electrons, on the other hand, can be quite easily removed from the atom ; ordinary friction will do this.

Splitting Atoms of Lithium into Atoms of Helium

Atoms of lithium have been split up into atoms of helium by bombarding the nucleus of lithium atom with protons obtained from hydrogen atoms. A stream of fast protons has been directed against a lithium screen. It has been found that in one case in a thousand million a proton managed to hit squarely the nucleus of an atom of lithium. The seven protons in the nucleus of an atom of lithium, the colliding proton and the four cementing electrons in the lithium nucleus form two groups of four protons and two electrons each, each group being what is known as the *alpha particle.** This particle is an atom of helium minus its two planetary electrons. The planetary electrons of the lithium atom are apparently jerked off into space in the collision. Thus, as you see the science about electrons and protons, *i.e.*, the electronic theory is not something in the nature of a guess, but is a well-established number of facts proved experimentally.

The Neutron

Another curious discovery made lately is that a proton and an electron, under certain circumstances, can come into such close union as to form a new particle which behaves quite differently to either a proton or an electron. This particle has been christened a *neutron.* The latter particle is of small interest to us at the moment, as little is known about it, and, as far as we know, it does not play any *rôle* in the phenomena which we are investigating at present.

Neutral Atoms

When an atom has its natural number of protons and electrons, *i.e.*, as many electrons as there are protons, every proton in the atom is balanced by its own electrons, so that all the attractive forces between protons and electrons and all the repelling forces between protons and between electrons are perfectly balanced. Such an atom is called a normal or a *neutral atom.*

Protonic Force

But, if for some reason or other, an atom happens to lose

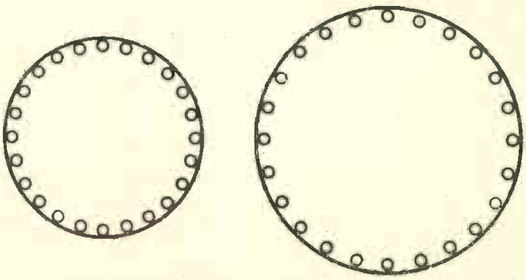


Fig. 10.—With the same quantity of Electricity a smaller Conductor will have a Higher Potential than the larger Conductor.

* Alpha particles are also emitted by radioactive substances.

one or more of its planetary electrons (normally it cannot lose anything else) some of the protons become unbalanced, and there is a surplus of *protonic force.*

Electronic Force

If, on the other hand, an atom gains a few electrons, the surplus electrons are unbalanced, and there is an excess of *electronic force.*

What Electrification is

This excess of either electronic or protonic force we call *electrification.* If an atom is to become electrified it must have either a deficit of electrons or a surplus of electrons. In other words, by electrification we mean either an excess of protonic forces when there is a deficit of electrons, or an excess of electronic forces when there is an excess of electrons.

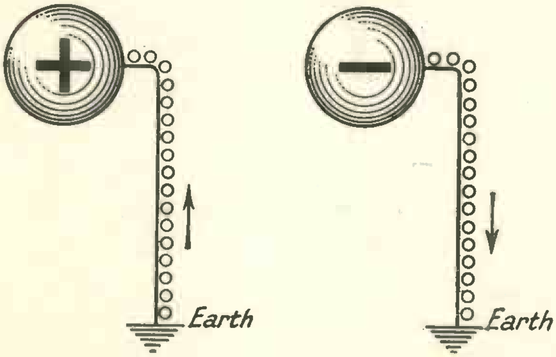


Fig. 11 (Left).—Electrons will flow to a Positively Charged Sphere from Earth. (Right).—Electrons will flow from a Negatively Charged Sphere to Earth.

Since the text-books call electronic electricity negative electricity, and protonic electricity positive electricity, from this point of view a deficit of electrons means a surplus of protons, *i.e.*, a surplus of positive electricity and a surplus of electrons means a surplus of negative electricity. Again the text-books say that when an atom is electrified it carries an *electric charge.* We can understand this in the case of a surplus of electrons. There are more electrons than there should be, hence the atom is *charged* with electrons and there is an electronic or a negative charge.

Explanation of a Positive Charge

But when there is a deficit of electrons which produces automatically a surplus of protons, the text-books call this a *positive charge.* We must be careful here to see the thing in its right perspective. A positive charge does not mean that more protons have been added to the atom. A positive charge means a predominance of protons in the atom and the only way such a predominance can be brought into existence is by removing a few electrons from the atom and thus unbalancing some of the protons.

Thus, it is clear that *a negative charge is an excess of electrons in the atom and a positive charge is a deficit of electrons in the atom.*

Reason for Repulsion of Like Charges

The text-books state that positive charges repel each other, that negative charges repel each other, but that a positive charge will attract a negative charge. This conclusion has been drawn from experimental evidence, but is not usually explained. It should be clear to you by now that the reason for repulsion of like charges is that in the case of positive charges on two bodies the predominant protons on each body exercise their repelling forces. In the case of negatively charged bodies it is the excess electrons on each body that are repelling each other. In the case of one body being charged negatively and the other body being charged positively, the surplus electrons on one body are attracting the unbalanced protons on the other body.

Electrons and Protons Possess Same Quantity of Electricity

As we already know an electron possesses precisely the same quantity of electricity as a proton. This means that if one atom has lost three electrons and the other atom has gained three electrons, the quantity of unbalanced electricity on each atom will be precisely the same, only in the case of the atom with a deficit of three electrons it is the protonic electricity (positive electricity) that is unbalanced or predominant and in the case of an atom with a surplus of three electrons it is the electronic electricity (negative electricity) that is unbalanced.

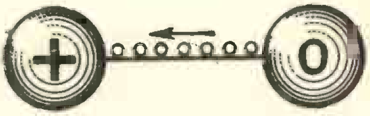


Fig. 12.—ELECTRONS WILL FLOW FROM A NEUTRAL SPHERE (O CHARGE) TO A POSITIVELY CHARGED SPHERE.

Only One Thing can make an Atom Electrified

It should be realised that *there is only one thing that can make an atom electrified* and that is the planetary electrons which can pass from atom to atom. The protons which are always bound to the atom can only play a passive *rôle* and make themselves felt in the absence of electrons which they should be balancing.

An Example of the Degree of Electrification

Let us consider two atoms of which one has a surplus of three electrons and the other has a surplus of two electrons. The degree of electrification of the atom with three surplus electrons is greater than that of the atom with only two surplus electrons. Similarly, if one atom has lost three electrons and the other atom has lost only two electrons the atom which has lost fewer electrons has a greater degree of electrification. In assessing the degree of electrification we have to use the number of electrons present or in deficit as our starting point. The text books call this degree of electrification the *electric potential* of the atom. Thus, the *electric potential is merely the number of electrons in surplus or in deficit per atom* (above or below the normal number of electrons in the atom).

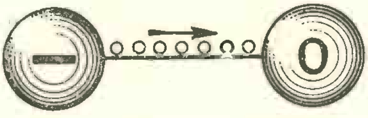


Fig. 13.—ELECTRONS WILL FLOW FROM A NEGATIVELY CHARGED SPHERE TO A NEUTRAL SPHERE.

An atom with a surplus of electrons has a higher potential than a neutral or normal atom. A neutral atom has a higher potential than an atom with a deficit of electrons.

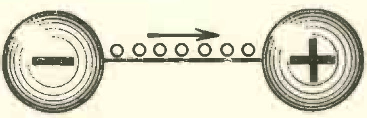


Fig. 14.—ELECTRONS WILL FLOW FROM A NEGATIVELY CHARGED SPHERE TO A POSITIVELY CHARGED ONE.

Circumstances under which Electrons Travel from an Atom

This will become clearer when you know that electrons will travel from an atom with a greater number of electrons to an atom with fewer electrons.* Thus, if an atom has an excess of four electrons and is brought into close contact with an atom that has only two electrons in excess, consider the force acting upon the excess electrons on each atom. In the first place, since all the protons on each atom are balanced there is no attractive force holding the excess electrons on either of the atoms. As far as the excess electrons on each atom are concerned one of the four surplus electrons is being repelled by three of its fellows and it is also being repelled by the two excess electrons on the other atom. The repulsion of the three fellow electrons is stronger than the repulsion of the two electrons on the other atom, so that the electron will take the line of least resistance and will migrate to the atom with fewer excess electrons. As soon as this happens the forces between the two atoms will become equalised.

When a normal atom is brought near an atom with a deficit of two electrons, the two exposed protons on the atom with the deficit will pull on an electron in the neutral atom which is held in place by its own balancing proton. The pull of two protons is stronger than the pull of a single proton and the electron in question will leave the neutral atom and will migrate to the other atom. Now, the neutral atom has lost one electron and the other atom has gained one electron. Each atom has now a proton unbalanced. This means equal forces between the two atoms and

* Both atoms being, naturally, of the same nature.

no further transfer of electrons can take place.

Electrons will migrate from an atom having a greater potential to an atom with a lower potential.

Difference of Potential

It is clear therefore that if electrons are to migrate from one atom to another or from one body to another there must be *a difference of potential.* In other words, there must be a difference in the number of electrons in excess or in deficit between the two atoms, or the atoms of the two bodies.

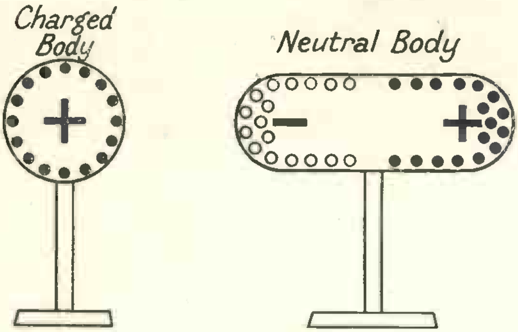


Fig. 15.—ELECTRONIC TIDES.

A positively charged body attracts the electrons in a neutral body to its near end.

Giving a Metal Sphere a Negative Charge

Let us take a metal sphere and communicate to it an electric charge, say a negative charge. This means that the atoms in this sphere will have a surplus of electrons. On investigating the distribution of the charge it is found that the surplus of electrons is only present in the *surface atoms.* The reason for this is that if any surplus electrons could find their way inside the sphere they would be repelling each other and would be compelled to get away from each other till they reach the surface atoms. There further escape is impossible, and thus all the surplus electrons are concentrated in the surface atoms.

Electric Potential of each Surface is the Same

Each surface atom has the same surplus. In other words, the electric potential of each surface atom is the same. The latter state of affairs applies only in the case of a metal sphere. An ebonite sphere behaves differently, as we shall see later.

Since it is the number of electrons in surplus or in deficit *per atom* that determines the electric potential, it is clear that the electric potential of the metal sphere as a whole is that of its single surface atom.

The quantity of electricity in surplus or in deficit on the sphere is equal to the quantity of electricity in surplus or in deficit in each surface atom multiplied by the number of surface atoms. Thus, a larger sphere can carry a greater quantity of electricity in surplus or in deficit than a smaller sphere.

Capacity of an Atom

It is clear that since the number of planetary electrons in an atom, under normal conditions, is limited, an atom can lose and it can also gain only a limited number of electrons. For this reason we say that each atom has a definite *capacity* for losing or gaining electrons. Similarly, a metal sphere, since its number of surface atoms is limited, has a definite capacity for losing or gaining electrons.

Capacity of a Sphere Depends on its Dimensions

The larger the sphere the more electrons it has to lose and the more electrons it can gain, as a whole. When the full capacity of the sphere is reached, it does not matter how many electrons we try to place on it or how many electrons we try to take away from it, we shall be unable to alter its electric condition.

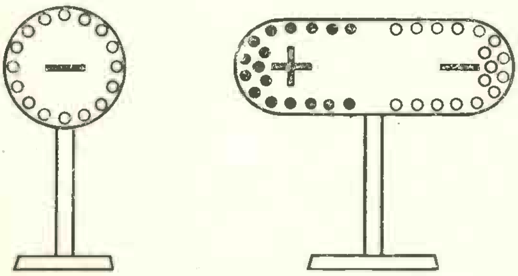


Fig. 16.—ELECTRONIC TIDES.

A negatively charged body repels the electrons in a neutral body to the far end.

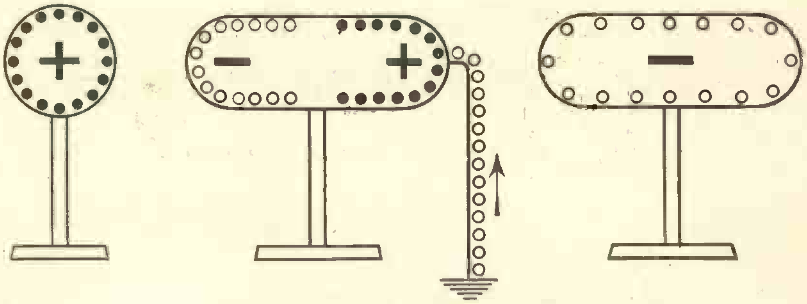


Fig. 17.—Electronic Tides.

If the neutral body while under the influence of a charged body is earthed, electrons will flow from earth to the positive end neutralising it. When both the earth connection first and the charged body next are removed the oblong conductor will remain with a negative charge.

It is clear that *the capacity of the sphere depends on its dimensions*.

Since the electric potential is the number of electrons per atom in surplus or in deficit, and the capacity of a sphere depends on the number of surface atoms, it is clear that

potential × capacity is equal to the total quantity of unbalanced electricity on the sphere.

Again: $\frac{\text{quantity}}{\text{capacity}}$ = electric potential of the sphere.

Similarly, capacity = $\frac{\text{quantity}}{\text{potential}}$.

Earth Always at Zero Potential

The earth is so large as compared with such a sphere that it can be considered to be always in a neutral condition, *i.e.*, at *zero potential*. It does not matter what we do to it by our puny human effort, we cannot raise its potential. This means that the earth will accept and will supply any number of electrons without feeling any difference. Thus, if we connect to earth a metal sphere by means of a short length of wire, whatever we do to the sphere we cannot electrify it. If we take away a number of electrons from its surface atoms, it will promptly compensate its deficit from the earth atoms.

Similarly if we communicate to the sphere a number of surplus electrons, it will get rid of them to earth and will remain unelectrified. Not so an ebonite sphere. Such a sphere will not only prevent the flow of electrons to earth or from earth to its surface, but will not share a charge amongst its surface atoms. In the case of a metal sphere if we electrify one spot of the sphere we have electrified the whole. In the case of an ebonite sphere, and for that matter a glass or a marble sphere, if we electrify a spot, only this spot will remain electrified. The atoms of the ebonite sphere will not share the surplus electrons or lose equally electrons all over the surface as they do in the case of a metal sphere.

Why Ebonite will not Conduct Electricity

The reason for this is that in metals the atoms of which are comparatively simple in their architecture can exchange electrons freely amongst them, while in the case of atoms constituting the molecules of ebonite, glass or marble, the structure is so complex and the planetary electrons are so closely bound to their atoms that quite a large force is required to get them away from their atoms.

For this reason we divide substances into two classes of conductors such as metals and insulators (or isolators), such as ebonite, glass, marble, mica, slate, rubber, silk, etc.

This is rather fortunate, as in this manner we can surround our conductors by insulating substances and prevent electrons from flowing to earth as well as prevent the earth electrons from reaching our conductors, as an insulating substance will prevent electrons from flowing.

THE PRE-TUNED THREE

By JAMES H. BOOT

THIS novel receiver, which is of particular interest to the woman of the house, has been designed especially for people who dislike having to tune or adjust their sets before receiving a station. Any one of four stations can be received simply by turning the set on and pressing a switch, for once the four pre-set condensers have been correctly adjusted no further tuning is necessary. It has been designed to receive the following four stations: London National and London Regional on the medium waveband and Daventry and Radio-Paris on the long waves. If preferred, one of the pre-set condensers can be tuned to your own local station.

Fig. 1.—THE COMPLETED RECEIVER.

To operate the set push the centre lever to the left for medium waves and press down the switch for the station required. For long waves press the switch to the right.

The Circuit

The circuit is a straightforward three-valve arrangement with leaky grid detector followed by two transformer coupled L.F. stages. By this means a high degree of amplification is obtained, bringing in the four stations mentioned as loud as can be desired. By an ingenious arrangement of aerial switching, which, by the way, is effected in one movement, that of switching the set on, all trace of Regional break-through on the long waves is eliminated. Four pre-set condensers, each controlled by a separate switch, are used instead of the usual variable condenser.

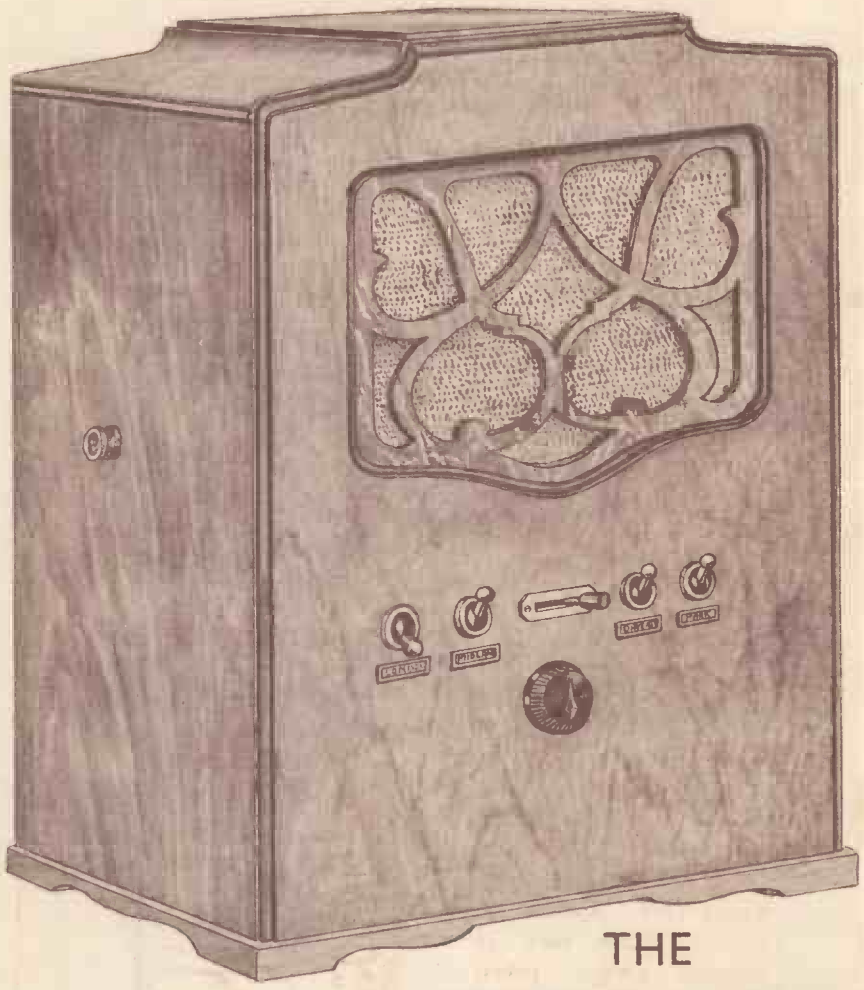
WITH PART 3.

DESIGN

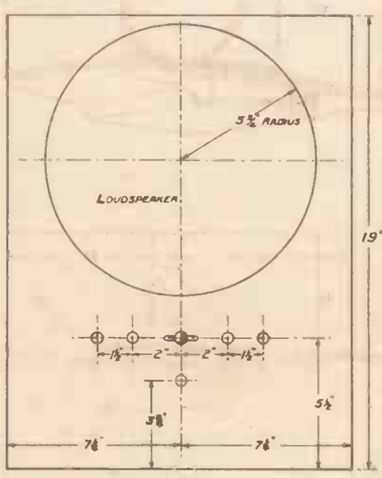
for "Complete

PRE-TUNED

THIS novel set is designed especially for the wom
than a set with single dial tuning, for any or
pressing a switch. Once the four pre-set condensers are
The switches are wired up before inserting the baseboa
be experienced in construction. The centre switch is
stations, and to the right for the long wave stations.

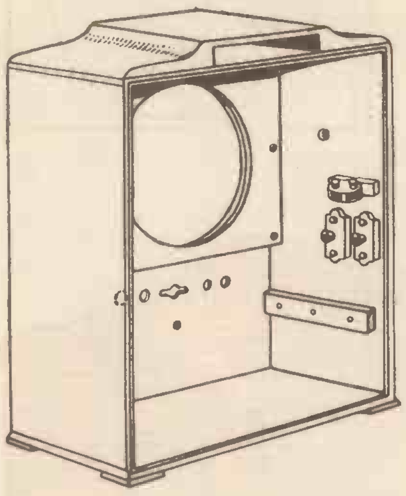


THE
PRE-TUNED THREE



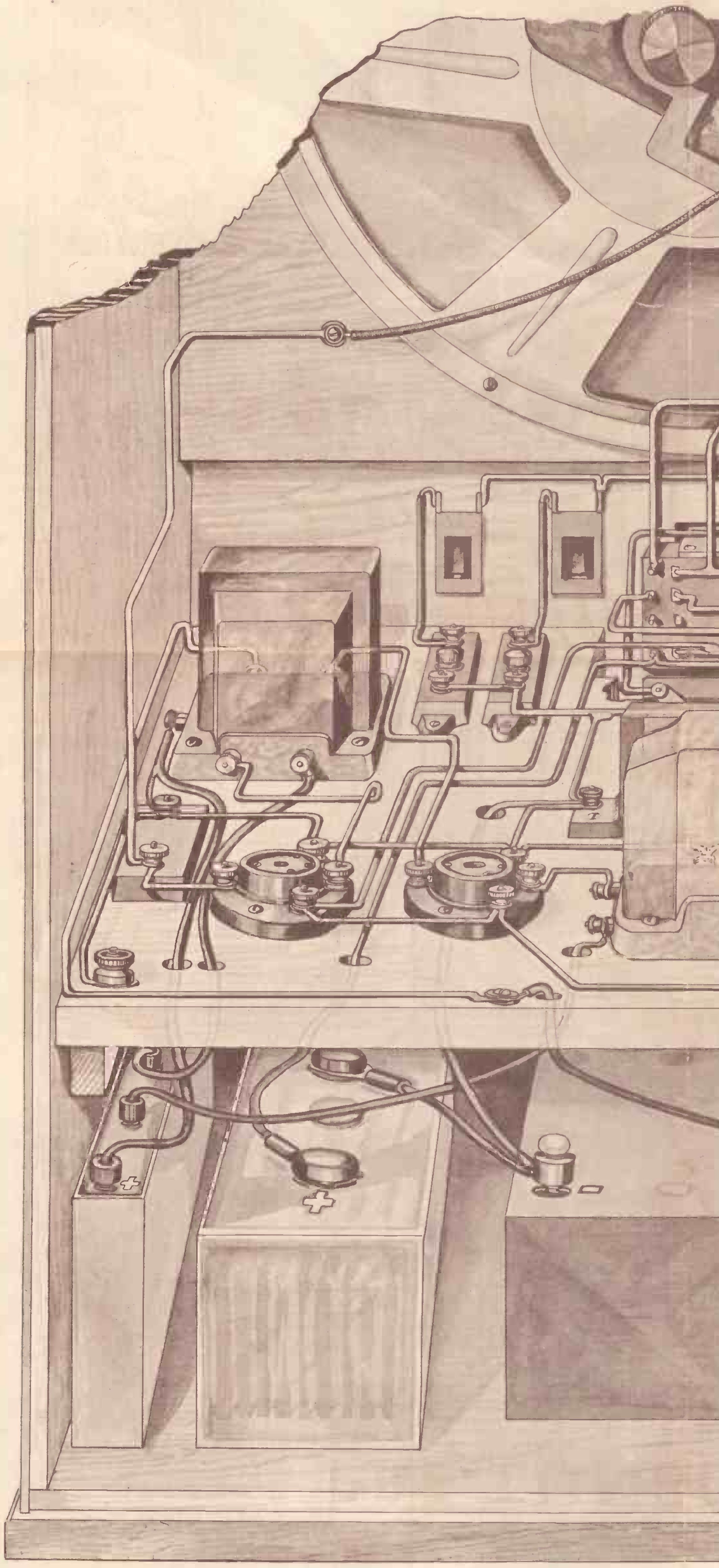
1st Stage.

Prepare the case by drilling holes for the switches and reaction condenser to the sizes of the components used. If necessary fit baffle board for loud-speaker.



2nd Stage.

Fit bearers for baseboard. Mark position of two aerial pre-set condensers, anti-break through choke and aerial terminal to right-hand side.



UNI-VIEW WIRIN

LIST OF COMPONENTS.

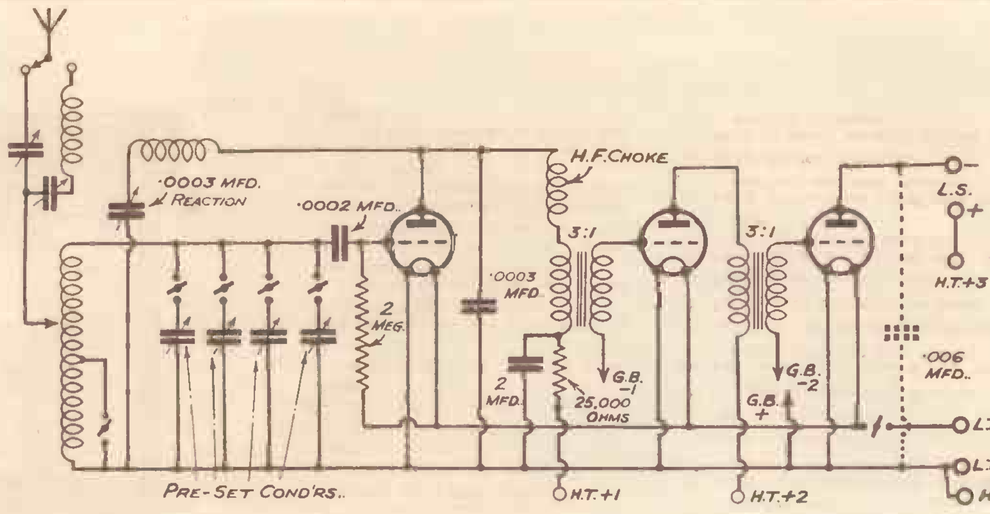
- 1 Cabinet (approx. 19 × 14½ in.).
- 1 Baseboard (5-ply wood), to fit cabinet.
- 2 pieces Wood (1 × 1 in.) for supporting baseboard.
- 1 L.F. Transformer, 3·1 (*Telsen Ace*).
- 1 L.F. Transformer, 3·1 (*Telsen Radiogrand*).
- 1 Dual Range Shielded Coil (*Lissen*).
- 1 H.F. Choke (*Lewcos*).
- 3 Valve Holders (*Lissen*).
- 6 Pre-set Condensers, 5 ·0003 max.; 1 ·001 max. (*Formo*).
- 4 Fixed Condensers, ·0003, ·0002, ·006, and 2 mfd. (*T.C.C.*).
- 1 ·0003 Reaction Condenser (*Polar*).
- 4 Switches (*Bulgin*).
- 1 4-way Double Throw Switch (*Wearite*).
- 1 Grid Leak (2 meg.) and Holder (*Lissen*).
- 1 Loud-Speaker Unit and Chassis (*Ormond*).
- 3 Terminals.
- 1 Spaghetti Resistance, 25,000 ohms (*Lewcos*).
- 1 Anti-break through Choke (*Lissen*).
- 4 Name-plates, with wording "Lon. Nat.," "Lon. Reg.," "Daventry," and "Radio Paris" (or whatever stations are required) (*Cellgrave*).
- Glazite Wire (2 coils).
- Flex (about 4 yards).
- Wander Plugs and Spade Terminals (*Belling Lee*).
- 3 Valves: 2 PM ILF; 1 PM₂A (*Mullard*).
- 1 120-volt H.T. Battery (*Lissen*).
- 1 2-volt Accumulator (*Lissen*).
- 1 9-volt Grid Bias Battery (*Lissen*).

CHART

e Wireless"

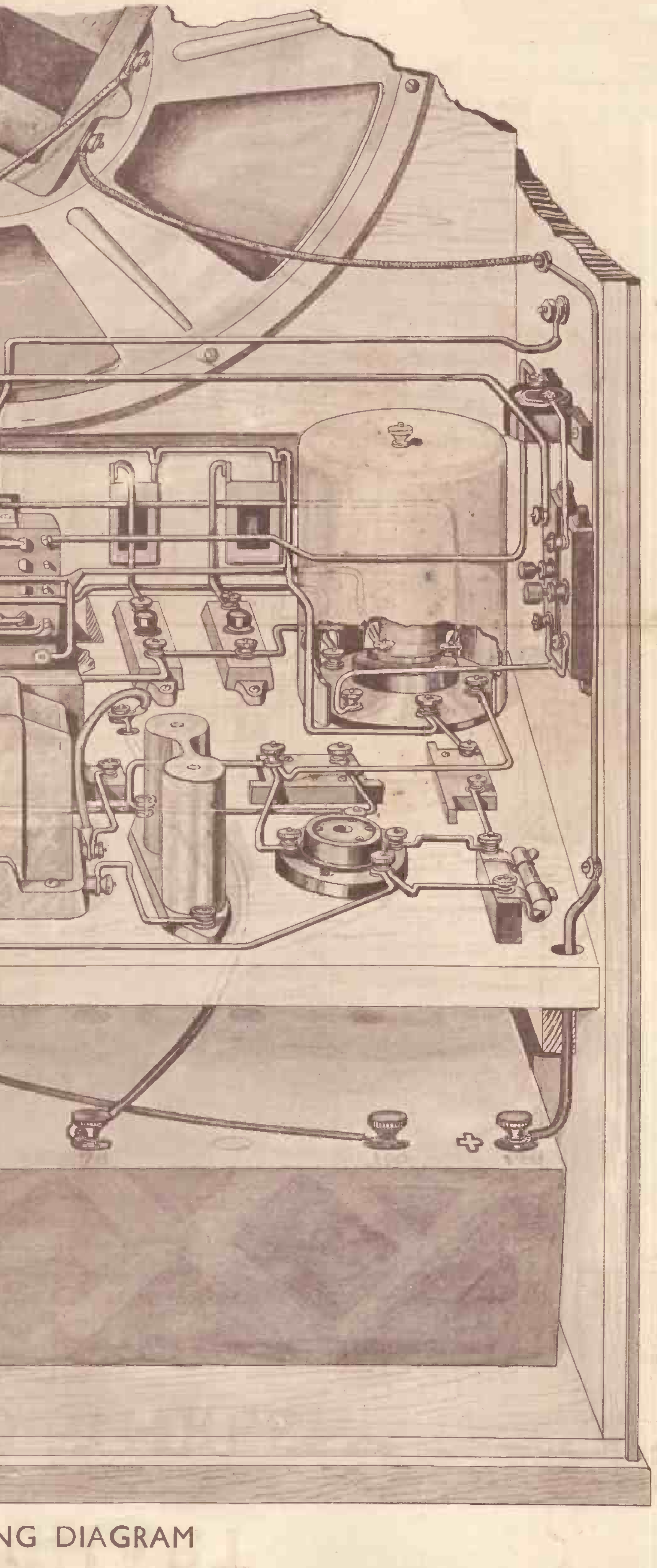
D THREE

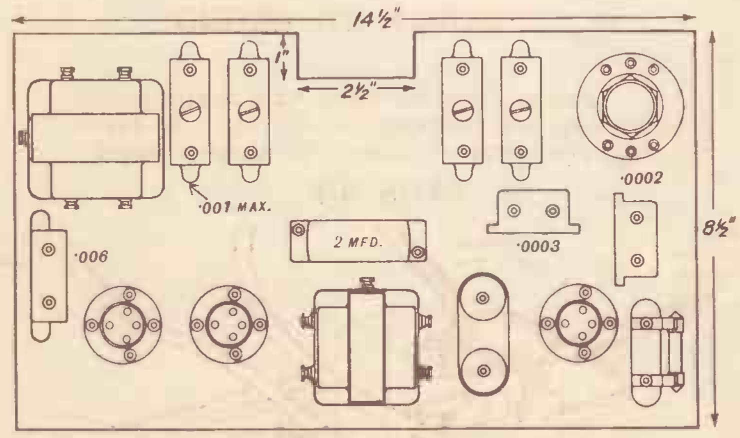
nan of the house. It is even simpler to handle
ne of four stations can be received simply by
e correctly adjusted no further tuning is required.
ard into the cabinet, so that no difficulty should
pressed to the left for the two medium wave



Circuit Diagram.

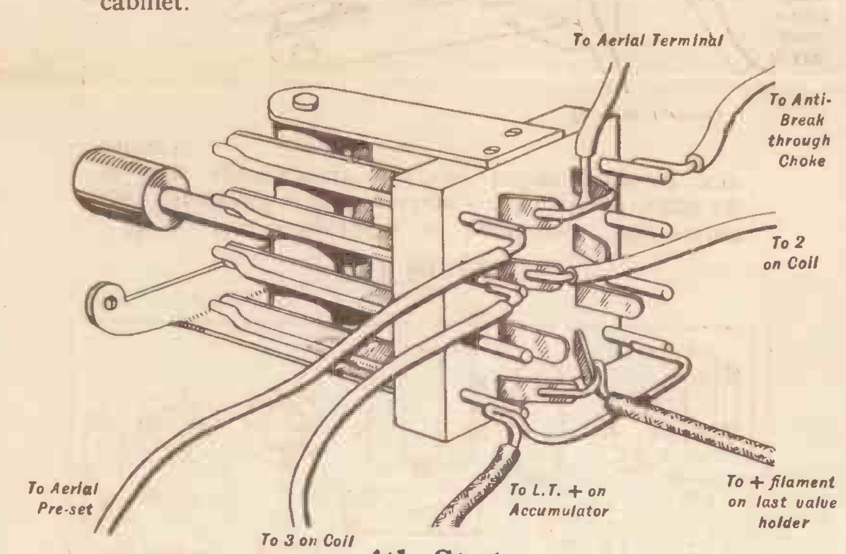
The circuit used consists of a straightforward detector and 2 L.F. arrangement. Tuning is effected by four pre-set condensers each controlled by a separate switch.





3rd Stage.

Mount the components on baseboard. Remember that the switches and reaction condenser are wired up in their approximate positions before inserting into cabinet.



4th Stage.

Solder wires to the switch as shown, and then wire up the set. The pre-set condensers are then adjusted individually to bring in the required stations.

ORDER OF WIRING.

1. L.T. plus to 3 valve holders.
2. L.T. minus to 3 valve holders and earth terminal on 1st transformer.
3. No. 1 on coil to grid condenser.
4. Grid condenser to grid leak and grid of detector valve.
5. Grid leak to L.T. plus detector valve.
6. L.T. minus to anode by-pass condenser.
7. No. 5 on coil to anode by-pass condenser. H.F. choke and plate of detector valve.
8. H.F. choke to P on 1st transformer.
9. H.T. plus on 1st transformer to 25,000 spaghetti and 2 mfd. condenser.
10. 2 mfd. condenser to L.T. minus 1st L.F. valve.
11. G on transformer to grid on 1st L.F. valve.
12. Plate of 1st L.F. valve to P on 2nd transformer.
13. Grid of power valve to G on 2nd transformer.
14. Earth terminal on 2nd transformer to L.T. minus on power valve.
15. No. 2 on coil to one side of each pre-set condenser and 2 mfd. condenser.
16. Each pre-set condenser to one side (earth side) of their respective switches.
17. Other side of first switch to grid condenser (or 1 on coil) and to other side of three other switches.
18. Flex leads with minus plugs for grid bias to G.B. terminals on both transformers.
19. Flex lead with plus plug for grid bias to earth terminal on transformer.
20. Flex lead with plus plug through baseboard to H.T. plus on 2nd transformer.
21. Flex lead with plus plug through baseboard to free end of spaghetti and terminal on baseboard.
22. Flex leads with one minus plug and one minus L.T. spade terminal to L.T. minus of 1st L.F. valve, or to L.T. minus connection on 2 mfd. condenser.
23. No. 4 on coil to aerial pre-set condensers.
24. Aerial pre-set condenser to anti-break through choke.
25. Aerial pre-set condenser to multi-contact switch. (See enlarged diagram.)
26. No. 3 on coil to switch.
27. No. 2 on coil to switch.
28. L.T. plus on power valve to switch.
29. L.T. plus spade terminal flex through baseboard to switch.
30. Anti-break through choke to switch.
31. No. 2 on coil to reaction condenser.
32. No. 6 on coil to reaction condenser.
33. Flex lead with plus plug from plus of speaker through baseboard to H.T. plus.
34. Earth terminal on transformer to ·006 condenser and earth connection.
35. Aerial terminal to switch.
36. Plate of power valve to speaker minus and ·006 condenser.

NG DIAGRAM

Components Required

1 cabinet (approx. 19 ins. × 14½ ins.).

1 baseboard, five-ply wood to fit cabinet.

2 pieces 1 in. × 1 in. wood for supporting baseboard.

1 L.F. transformer, 3·1 (*Ferranti*).

1 L.F. transformer, 3·1 (*Ferranti*).

1 dual range shielded coil (*Lissen*).

1 H.F. choke (*Lewcos*).

3 valve holders (*Lissen*).

6 pre-set condensers: 5, ·0003 max.; 1, ·001 max. (*Formo*).

4 fixed condensers, ·0003, ·0002, ·006, 2 mfd. (*T.C.C.*).

1 reaction condenser, ·0003 (*Polar*).

4 switches (*Bulgin*).

1 4-way double-throw switch (*Wearite*).

1 2-meg. grid leak and holder (*Lissen*).

1 loud speaker unit and chassis (*Ormond*).

3 terminals.

1 Spaghetti resistance, 25,000 ohms (*Lewcos*).

1 anti-break through choke (*Lissen*).

4 nameplates (*Cellgrave*).

Glazite wire, 2 coils.

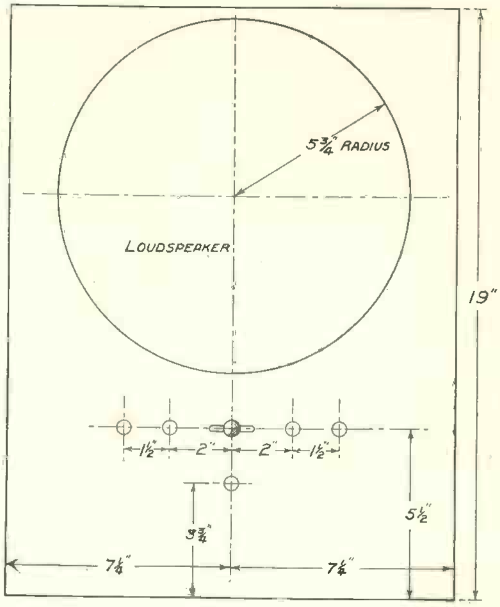


Fig. 2.—How to Prepare the Cabinet.

Drill holes as shown for the switches and reaction condenser. If necessary fit baffle board for loud speaker.

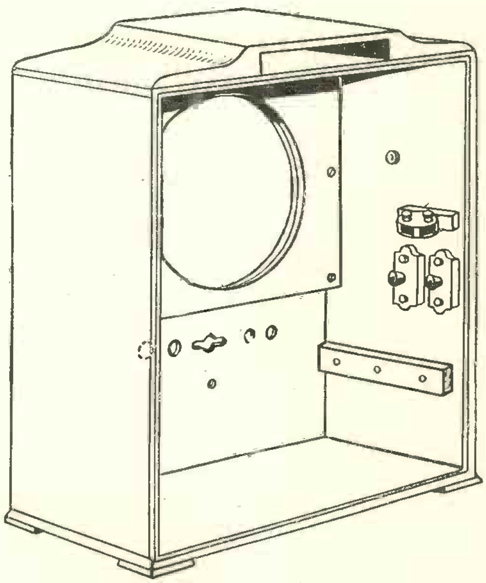


Fig. 3.—Fitting the Bearings for the Baseboard.

Mark also the positions to be taken by the two aerial pre-set condensers, anti-break through choke and fix aerial terminal.

Flex, about 4 yards.

Wander plugs and spade terminals (*Belling Lee*).

3 valves: 2, P. M. 1 L. F.; 1, P.M.2A. (*Mullard*).

1 120-volt H.T. battery (*Lissen*).

1 2-volt accumulator (*Lissen*).

1 9-volt grid bias battery (*Lissen*).

The Cabinet

The choice of cabinet is left to the taste of the person who is building the set. Almost any cabinet in which the loud speaker, set and batteries can be incorporated as a whole will be found most satisfactory. The set can, however, be built in a separate cabinet, with the loud speaker as an additional unit, if preferred.

Preparing the Cabinet

The first thing to do is to drill in the front of the cabinet the holes for mounting the switches and reaction condenser. Details of suitable dimensions are given in Fig. 2, but here again final choice is left to the reader's discretion. A brace and bit should be used, the size of the bit depending on the diameter of the switches. The holes should be just big enough to allow the switches to pass through easily, as all the wiring is completed before the switches are inserted in the cabinet. The hole for the multi-contact switch should be cut out with a small key saw.

(A later article deals with the construction of various kinds of cabinets, and almost any of these could be used for this set.)

Fixing the Supports

Next fix the two pieces of wood which form the supports for the baseboard. These are screwed to the sides, about $5\frac{1}{2}$ inches from the bottom, so that space is left below the baseboard for housing the batteries. Next mark the position of the two aerial pre-set condensers and anti-break through switch, and fix the aerial terminal on the side.

The Nameplates

The four nameplates are glued on to the front of the cabinet immediately under the four holes for the switches. Reading from left to right, they should be placed in the following order: "London National." "London Regional," "Daventry" and "Radio-Paris."

Nameplate for Your Local Station

If, however, you intend using the set for receiving your local station instead of one of the stations mentioned above, a nameplate for this station should be substituted.

Mounting the Loud speaker

The loud speaker chassis is mounted directly on to the cabinet, behind the fret provided. With some types of cabinets it may be found necessary to make a baffle board on which to mount the loud speaker. Make sure that the loud speaker is fixed firmly to prevent any possibility of its vibrating loose. The loud speaker unit should be fixed to the chassis before fixing the chassis in the cabinet.

The Baseboard

The baseboard consists of a piece of 5-ply wood cut to the internal dimensions of the cabinet. Holes should be drilled

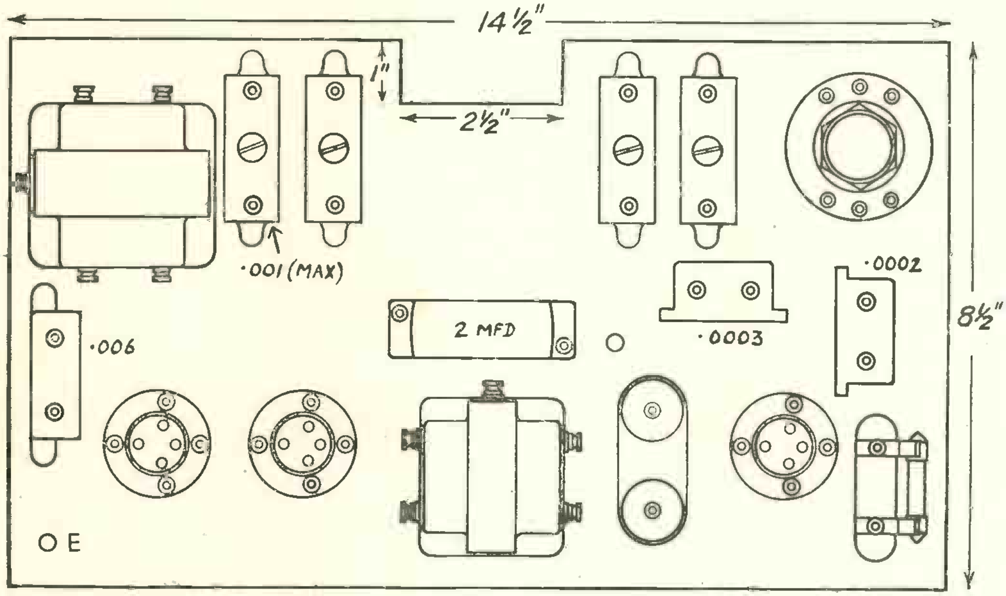


Fig. 4.—Position of Components on Baseboard.

The components should be laid in their approximate positions before fixing down.

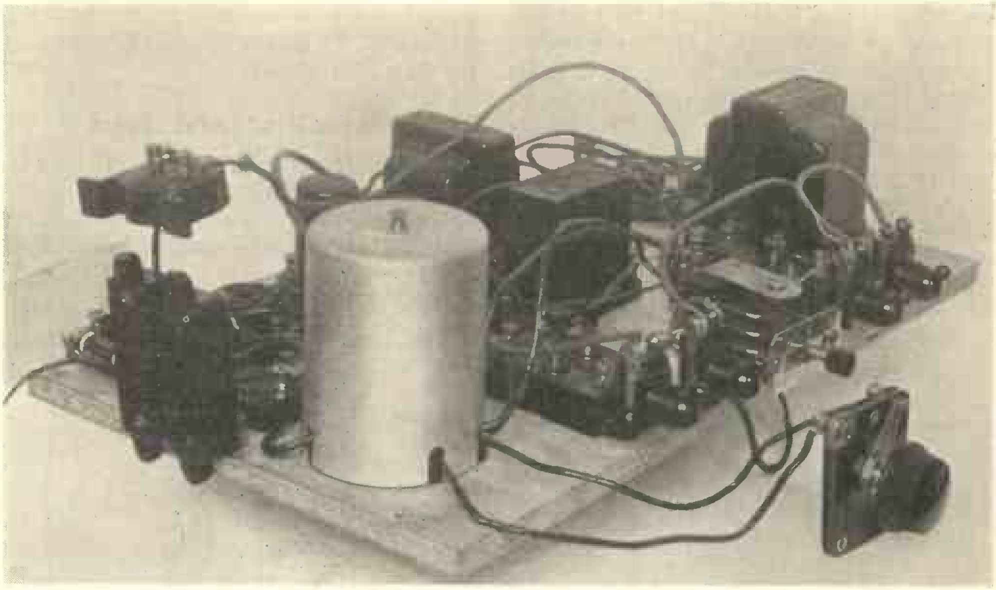


Fig. 5.—THE BASEBOARD WIRED UP READY FOR INSERTING IN CABINET.

Note specially that the switches, reaction condenser, aerial pre-set condensers and anti-break through choke are all wired in position on the baseboard. The wire will be found to be stiff enough to hold these components in their approximate positions.

at each of the corners, for fixing to the two supporting pieces in the cabinet.

A small piece is cut out at the centre of the front (see Fig. 4) to allow for the reaction condenser.

Mounting the Components

The next step is to place the components on the baseboard, and lay them out in their approximate positions as shown in Fig. 4. This method will be found better than fixing one component at a time, so that if components other than those actually specified are used, any necessary adjustments can be made. Drill small holes by the side of the L.T.— terminal of the power valve and the H.T.+

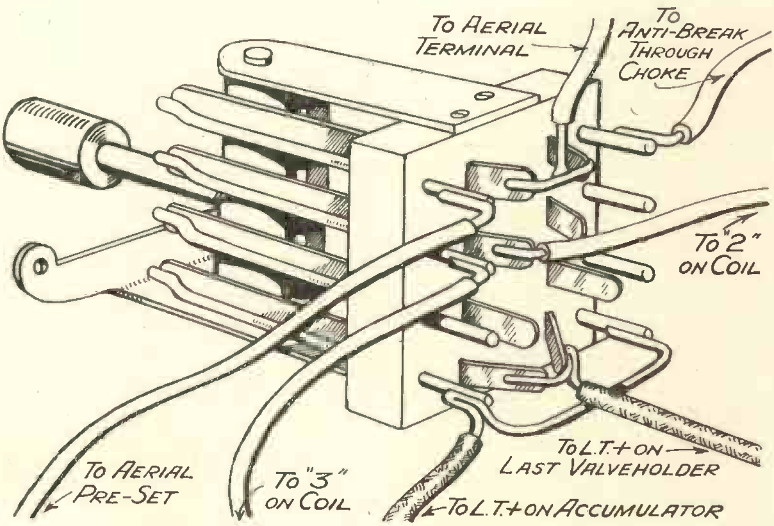


Fig. 6.—ENLARGED VIEW OF MULTI-CONTACT SWITCH WIRING.

This shows where each wire is connected to and will be found of assistance when wiring the switch.

terminal of the last transformer. Fix a terminal at the bottom left-hand corner for earth and another an inch or so above the H.F. choke for connecting the Spaghetti resistance and H.T. 1 lead. The ·001 maximum pre-set condenser, which is used for Radio-Paris, should be placed farthest away from the coil, next to the second L.F. transformer.

Fig. 7.—FIXING THE SWITCHES ON THE FRONT AFTER INSERTING THE BASEBOARD IN THE CABINET.

Fitting the Valve Holders

Before screwing down the valve holders take care to see that the plate terminals are all pointing in the same direction. This will be found to be a convenience when wiring up the filaments.

The Multi-Contact Switch

The next thing is to prepare the 4-way double-throw switch, ready for wiring to the baseboard components. First lay the switch in its approximate position and measure sufficient lengths of wire for soldering to the switch. Fig. 6 shows an enlarged view of the switch, and the wires are connected in the following order :—

1. Join contacts 2 and 3.
2. Join contacts 8 and 9.
3. Join contacts 7 and 10.
4. To contact 1, a connection for medium wave pre-set condenser.
5. To contact 4, a connection for the anti-break through choke.
6. To contact 5, a connection for 3 on coil.
7. To contact 6, a connection for 2 on coil.
8. To contacts 2 and 3, a connection for aerial terminal.
9. To contacts 8 and 9, a connection for L.T.+ of accumulator.
10. To contacts 7 and 10, a connection for L.T.+ of third valve holder.

How the Switch Works

Although this switch may appear to be involved in its connections it adds greatly to simplicity of operation. There are three positions on the switch, "OFF," "MEDIUM," and "LONG." When in the first position no current is being passed and the set is off. When switched over to the left, *i.e.*, to the MEDIUM position, the following operations take place :—

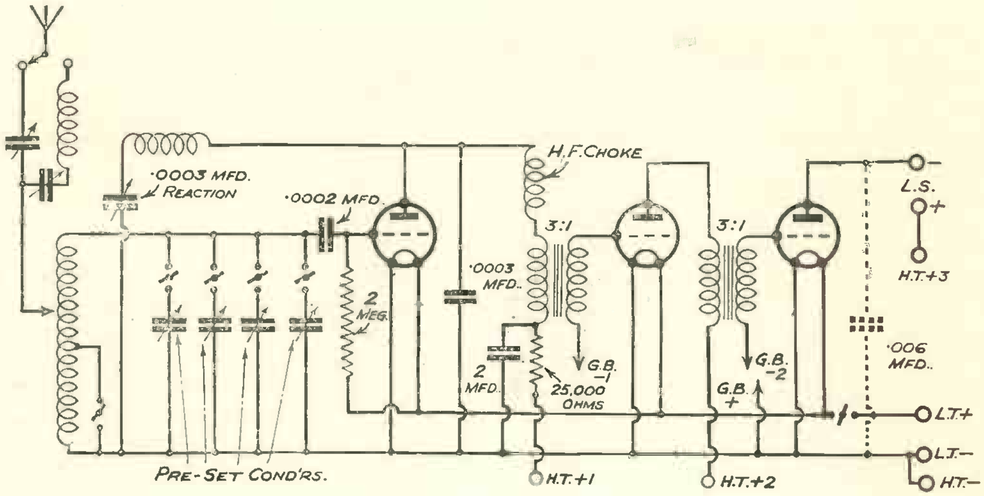


Fig. 8.—CIRCUIT DIAGRAM FOR THE PRE-TUNED THREE.

The long wave winding on the coil is shorted out, the aerial is switched on to the pre-set condenser adjusted for this waveband and the set is switched on.

When in the LONG position the long wave winding is brought into use, the aerial switched over to the anti-break through choke and specially adjusted pre-set condenser, and the set is switched on. Thus it will be seen that three operations are carried out by one movement in each case.

The Pre-set Condensers

As already mentioned tuning is effected by means of four pre-set condensers, each controlled by a separate switch. A suitable value for these condensers for receiving the National (medium and long) and Regional programmes is ·0003 mfd. maximum. For tuning Radio-Paris a condenser of ·001 mfd. maximum will be found satisfactory.

If your local station happens to be on a wavelength higher than the London Regional, *i.e.*, 356 metres, it may be found necessary to use another ·001 mfd. maximum condenser in place of one of the ·0003 mfd. condensers.

Volume Control

The control of volume is effected by means of a ·0003 mfd. reaction condenser which is situated immediately below the multi-contact switch. If volume is too great with the condenser at its minimum position, the station in question can be slightly detuned by adjusting its particular pre-set condenser.

Tone Control

It will be seen that a ·006 mfd. condenser has been inserted between loud speaker negative and earth. This is entirely optional, and it may be found that the tone is sufficiently pleasing without this condenser.

Alternatively experiments may be made with condensers of values between ·002 mfd. and ·006 mfd.

Wiring the Components

The wiring of the components follows usual practice. Grid leads should be kept as short as possible (the components have been arranged to ensure this) as this helps to eliminate interaction and pick-up in the set. The four switches, the multi-contact switch, the aerial pre-set condensers and the anti-break through choke are all wired up as part of the baseboard assembly, and it will be found that the Glazite wire is quite firm enough to hold them in their approximate positions until ready for inserting into the cabinet.

A convenient method of carrying out the wiring is as follows :—

1. L.T.+ to three valve holders.
2. L.T.— to three valve holders.
3. No. 1 on coil to grid condenser.
4. Grid condenser to grid leak and grid of detector valve.
5. Grid leak to L.T.+ of detector valve.
6. L.T.— to anode by-pass condenser.
7. No. 5 on coil to anode by-pass condenser, H.F. choke and plate of detector valve.
8. H.F. choke to P on first transformer.
9. H.T.+ on first transformer to 25,000 Spaghetti and 2 mfd. condenser.
10. 2 mfd. condenser to L.T.— of first L.F. valve.
11. G on transformer to grid of first L.F. valve.
12. Plate of first L.F. valve to P on second transformer.
13. Grid of power valve to G on second transformer.
14. Earth terminal on second transformer to L.T.— on power valve.
15. No. 2 on coil to one side of each pre-set condenser and 2 mfd. condenser.
16. Each pre-set condenser to one side (earth side) of their respective switches.
17. Other side of first switch to grid condenser and to other side of three other switches.
18. Flex leads with minus plugs for G.B. to G.B. terminals on both transformers.
19. Flex lead with plus plug for G.B. to earth terminal on transformer.
20. Flex lead with plus plug through baseboard to H.T.+ on second transformer.
21. Flex lead with plus plug through baseboard to free end of Spaghetti and terminal on baseboard.
22. Flex leads with one minus plug and one minus L.T. spade terminal to L.T.— of first L.F. valve.
23. No. 4 on coil to aerial pre-set condenser.
24. Aerial pre-set condenser to anti-break through choke.
25. Aerial pre-set condenser to multi-contact switch.
26. No. 3 on coil to switch.
27. No. 2 on coil to switch.
28. L.T.+ on power valve to switch.
29. L.T.+ spade terminal flex through baseboard to switch.
30. Anti-break through choke to switch.
31. No. 2 on coil to reaction condenser.
32. No. 6 on coil to reaction condenser.
33. Earth terminal on transformer to earthed side of ·006 condenser.
34. Plate of power valve to ·006 condenser.

Loud speaker and Aerial Leads

A lead is taken direct from loud speaker + to H.T.+ and from loud speaker — to plate of the power valve. The aerial lead on the multi-contact switch is then connected to the aerial terminal.

When wiring the coil connections make sure that sufficient wire is allowed for the screen to be fitted, taking care that there is no bare wire to touch on the coil screen.

Inserting Baseboard into Cabinet

Provided that the instructions given above have been carried out, it will be found that the switches will fit into the holes prepared for them when the baseboard is inserted into the cabinet. They should now be fixed in position from the front ; the knob fixed on to the reaction condenser and the aerial pre-sets and anti-break through choke screwed in their positions at the side.

Connecting up the Batteries

The batteries are placed in the space left under the baseboard and connected as follows : H.T.1 from Spaghetti at 60–80 volts tapping ; H.T.2 from H.T. of second transformer at 80–100 ; and H.T.3 direct from loud speaker+ in 120. These H.T. voltages can be adjusted until the best results are obtained. G.B.+ from earth terminal on second transformer should be placed in positive side of grid bias battery. G.B.—1 from first transformer at 1·5 tapping and G.B.—2 from second transformer at 7·5–9.

With regard to the grid bias, the best plan is to follow the instructions given by the valve makers, using whatever grid bias they recommend for the H.T. voltage used.

HINTS ON OPERATING THE SET

Having connected up the accumulator and the aerial and earth, the set is now ready for operation. Switch the multi-contact switch over to the left, that is to the medium wave side, and press down the farthest of the two left-hand switches. With a small screwdriver adjust the pre-set condenser immediately behind this switch until the National programme is heard at the loudest strength obtainable, first making sure that the reaction condenser is at minimum.

If necessary, increase the reaction to obtain a sufficiently loud signal, and readjust the pre-set condenser until reception is satisfactory.

Now switch off the National programme and press down the second switch, and adjust the second pre-set condenser until the Regional programme is heard.

If there is any interference from one station when receiving the other then turn the medium wave aerial pre-set in an anti-clockwise direction and readjust the tuning pre-set condensers. Once satisfactory reception is obtained from both stations the two condensers can be fixed permanently by means of the fixing nuts provided for this purpose.

Now switch over to the long waves and adjust the two remaining pre-set condensers in a similar manner until Daventry and Radio-Paris can be heard. Adjust the other aerial pre-set condenser as before to obtain maximum selectivity.

Tuning is Critical

It will be found that tuning is quite critical and only a slight movement is all that is necessary to bring in the station required. Remember that only the switch controlling the station required must be pressed down when reception from that station is required. The other three switches must all be off.

INSERTING A VARIABLE CONDENSER

This set can quite easily be adapted for tuning in the ordinary manner. A variable condenser of ·0005 mfd. and an additional switch are the only extra components needed. These can be mounted on the side of the cabinet beside the aerial pre-set condensers.

One side of the switch is wired to the common side of the four pre-set condensers, and the other side to one of the terminals on the variable condenser. A wire is taken from the other variable condenser terminal to 4 on the dual-range coil.

Tuning by Variable Condenser

When using the variable condenser, see that the four switches at the front are all off, and switch the set on to either medium or long waves as required. Press down the new switch and the variable condenser can be used for tuning in the ordinary way. Used in conjunction with a good aerial and earth at least a dozen foreign stations should be received at good loud-speaker strength.

To revert to the four set stations, switch out the variable condenser and operate the set from the front again.

SUBSTITUTING A MOVING COIL SPEAKER FOR A CONE SPEAKER

SOMETIMES when a permanent magnet moving coil loud speaker is connected to a set in place of an ordinary cone type loud speaker, a noticeable loss of signal strength is experienced although the improvement in tone is satisfactory.

This is probably because only a small power valve is being used in the set, which, although sufficient to work the cone speaker, is not powerful enough to drive one of the permanent magnet moving coil type. The remedy is to use a more powerful power valve.

This will necessitate adjustment of the H.T. supply. It is not only sufficient to increase the voltage applied to the power valve, but the battery must be capable of delivering the necessary amount of current. At least 20 milliamps should be allowed for working a super-power valve, so that if the other valves in the set take about 5 or 6 milliamps between them, then the H.T. battery used must be capable of delivering about 30 milliamps in all.

REGULATIONS GOVERNING THE USE AND INSTALLATION OF WIRELESS MAINS SETS

By H. W. JOHNSON

THE use of the electric light mains for the supply of current required for valves and moving coil loud speakers of wireless receivers is now the general practice, and only in cases where no mains supply is available are batteries and accumulators used. If the wireless apparatus or the wiring which connects it to the mains is defective a "shock," which may have fatal results, may be received, or a fire may be started causing disastrous results. Consequently all mains wireless sets and the connecting wiring and accessories are subjected to regulations which govern their construction, installation, and use. These regulations have been formulated by the Institution of Electrical Engineers to ensure that all mains sets shall be of sound construction and that the wiring and controlling accessories from the "mains" to the sets shall be safe. The local supply companies' inspectors examine the wiring and controlling accessories for safety and conformity with the regulations, and the radio manufacturers construct the sets to a specification which conforms with the regulations. Home constructors and wireless amateurs should make themselves thoroughly acquainted with these regulations, so that their sets will be constructed and installed in accordance with them.

Fig. 1.—A CONNECTION TO A LAMPHOLDER IS NOT RECOMMENDED.

Showing the unsightly and unworkmanlike job that often results.

The Use of a Lampholder Connection is Not Recommended

Taking the supply of current from an existing lampholder is not to be recommended because of the following reasons:

(1) If the apparatus only takes a small current, less than 2 amperes, then the current fuses for this lampholder circuit, which will include other lamp positions, will not adequately protect the wireless apparatus from excess current.

(2) The connection between the lampholder adaptor and lampholder is not rigid, and not shrouded with insulating material unless H.O. type accessories are used.

Fig. 2.—THE PROPER WAY TO MAKE A HOLE IN A METAL CASE.

The hole should be bushed as shown.

Fig. 3.—THE INCORRECT WAY OF MAKING A HOLE IN A METAL CASE.

Showing how the covering becomes damaged if the hole is not bushed.

Fig. 4.—TESTING THE INSULATION RESISTANCE OF AN ACCUMULATOR TO EARTH.

The accumulator is placed on a metal base, and one end of a megger is connected to one terminal of the accumulator, and the other end to the metal. The resistance should not be less than 2 megohms when tested with a pressure of 500 volts.

(3) The job is unsightly and unworkmanlike.

(4) If the apparatus takes a current of more than 2½ amperes the current carrying capacity of the ordinary B.C. lampholder and its flexible from the ceiling rose is not large enough, and probably the adaptor connection in the lampholder will heat up and the insulation of the flexible will soon perish.

Wireless Apparatus. Material to be Used for the Cases

The containing cases may be constructed of :

(1) Metal or non-ignitible material ;

(2) Mahogany, teak, walnut or English oak ;

(3) Other material if fitted with a non-hygroscopic and non-ignitible lining.

Metal cases should be earthed and provided with a suitable terminal for this purpose. The earthing connection can be made to a water pipe.

All holes in cases through which cables pass should be bushed.

The general temperature of the air inside the cases when the apparatus is working should not exceed 120° Fahrenheit.

Isolation of the Earthing Wire from the Supply Mains

The earth wire from the set must not be in connection with any conductor of the apparatus which is directly connected to the supply mains. A mica or paper dielectric condenser of 2 microfarads capacity, connected in the wiring of the set to the earth terminal, will effectually isolate the earth wire from the supply mains.

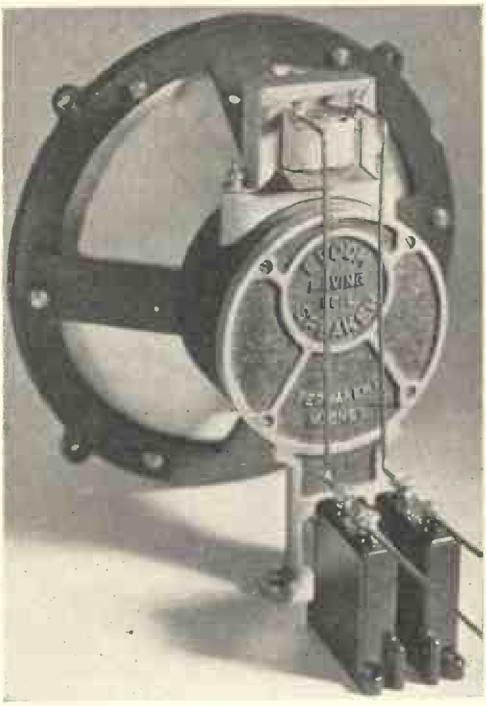


Fig. 5.—ISOLATING A LOUD SPEAKER FROM ANY WIRING IN THE SET WHICH IS DIRECTLY CONNECTED TO THE MAINS SUPPLY.

This is done by placing a condenser in series with each conductor to the loud speaker.

Accumulators Used in Conjunction with D.C. Mains Sets

When accumulators are used to supply the valve filament current of receivers whose H.T. current is supplied from the D.C. mains, they should be of the glass box type, and their insulation resistance to earth be not less than 2 megohms when tested with a pressure of 500 volts, or twice the working pressure of the mains, direct current.

Reason for Isolating the Earthing Wire and Accumulators

The reason for the isolation of the earth wire is that the supply will generally be given from an "outer" and the "neutral" of a three-wire system, in which the neutral is permanently earthed at the source. The potential of the neutral is midway between that of the two "outers." In a receiving set the H.T. negative is usually connected to the earth terminal, either directly or through the L.T. wiring. Now if the supply is given from the outer whose potential is below that of the earth, this outer would be connected to the H.T. negative and therefore, if directly earthed, would cause a short circuit and blow the fuses, therefore the condenser which is connected in the circuit will prevent this happening and will effectually isolate the earthing wire from the supply mains. This particularly applies to direct current systems of supply.

The Type of Condenser to be Used

The condenser which is used should con-

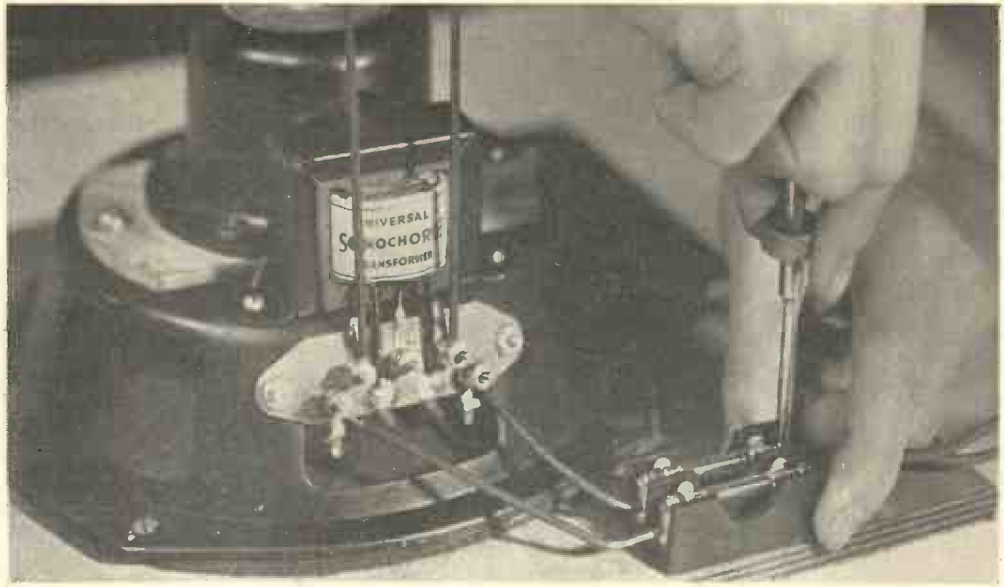


Fig. 6.—PROTECTING THE FIELD COIL CIRCUIT OF A MOVING COIL LOUD SPEAKER WITH FUSES.
When the loud speaker is separate from the set the field coil circuit must be efficiently protected, as fairly large currents are required to produce the field.

form to the British Standard Specification for mica dielectric or paper dielectric condensers for use in circuits in which the pressure does not exceed 300 volts. This condenser is tested with a pressure of 600 volts direct current.

Isolation of the Aerial from the Supply Mains

When the supply to the set is from direct current mains the aerial should be connected to the apparatus either through a condenser which is connected in series with the wiring of the set to the aerial terminal, or through a double-wound high-frequency transformer. If the supply is alternating current, and it is fed to the set without the use of a double-wound mains transformer, the aerial must be isolated from the apparatus in the same manner as required for a direct current supply, only if a condenser is used its capacity must not be greater than ·001 microfarad.

Reason for Isolating the Aerial

The reason for isolating the aerial from the apparatus with a double-wound high-frequency transformer or a condenser is to ensure that the aerial cannot be energised to a dangerous potential by contact with any apparatus or wiring of the set directly connected to the mains supply. When the supply is alternating current the size of the condenser is limited to ·001 microfarad to reduce the capacity current through it to a safe value.

The Insulation of the Double-wound High-frequency Transformer

The insulation of this transformer

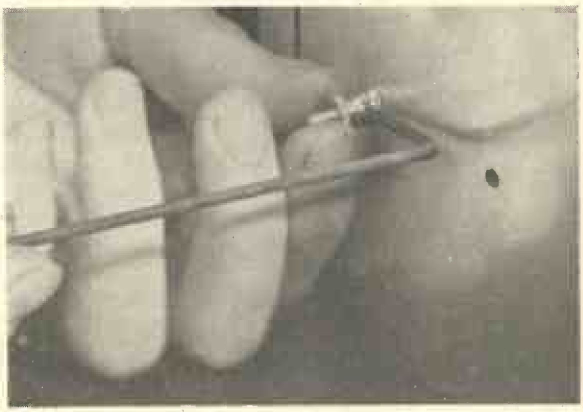


Fig. 7.—METAL CASES SHOULD BE EARTHED.

must be capable of withstanding a test pressure of 600 volts.

The Type of Condenser to be Used for Isolating the Aerial

The condenser must conform to the British Standard Specification for mica dielectric or paper dielectric condensers for use in circuits in which the pressure does not exceed 300 volts, and tested with a pressure of 600 volts direct current.

Loud Speakers and Headphones

Loud speakers and headphones must be connected to the receiving set through a double-wound transformer, or, alternatively, a condenser must be connected in series with each conductor to the loud speaker or phones. This ensures they are isolated from any wiring in the set which is directly connected to the mains supply.

Field Coil Circuits of Moving Coil Loud Speakers

When the loud speaker is of the moving coil type, and separate from the set, the field coil circuit must be efficiently wired and protected with fuses, as fairly large currents are required to produce the field.

Double Wound Mains Transformers

When the supply to the set is alternating current the isolating condenser in the aerial, earth and loud speaker leads may be omitted, provided special care is given to the construction and connections of the mains transformer. This must have entirely independent sets of windings, one of which is specially well insulated from the rest, or is separated from them with a metal screen which is connected to the core of the transformer and earthed.

The ends of this winding are the only points which are connected to the mains. The valve filament heaters, H.T. eliminators, loud speaker magnet coils, rectifiers, etc., are fed from the other transformer windings. The insulation resistance between the winding connected to the mains supply and all other windings should not be less than 20 megohms, when tested with 500 volts pressure D.C., or twice the supply pressure, whichever is the greater, and the insulation capable of withstanding a test pressure of 1,000 volts alternating current.

Fig. 8.—Mains Terminals should be Shrouded.

To prevent accidental contact, terminals which are alive from the mains supply should be as shown in the mottled case and not as in the wooden set.

Protection of Live Parts and Terminals

To prevent accidental contact with parts of the set and terminals which are alive from the mains supply and are exposed, such parts and terminals must be efficiently guarded. This will mean that terminals must be completely shrouded with insulating material and the parts enclosed in a metal case which is earthed.

Insulation Resistance of Mains Sets

The insulation resistance between the mains input terminals and the aerial, earth and loud speaker terminals should not be less than 2 megohms when tested with a pressure of 500 volts D.C., or twice the

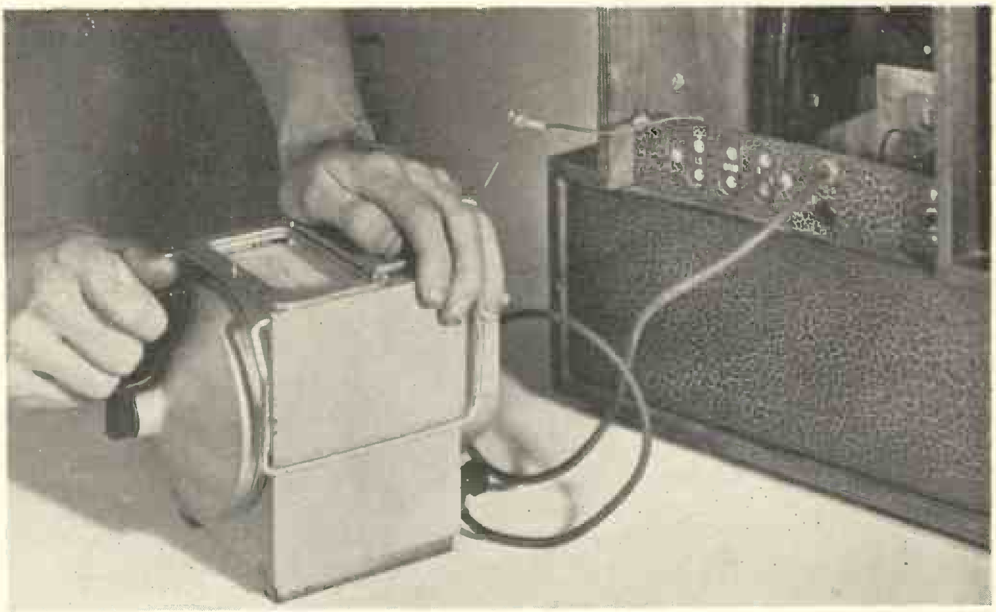


Fig. 9.—TESTING THE INSULATION RESISTANCE BETWEEN MAINS INPUT TERMINALS AND LOUD SPEAKER TERMINALS, WITH A MEGGER.

This should not be less than 2 megohms when tested with a pressure of 500 volts D.C., or twice the working pressure of the mains, whichever is greater.

working pressure of the mains, whichever is the greater.

Precautions to be taken when tracing "faults"

When conducting voltmeter tests with the object of tracing "open circuits" and other "faults" in a mains receiving set which is energised, the bared ends of the testing leads which are used to make temporary connections with the various accessories and wiring should not be held with the bare hands. Insulated testing spears should be used; these consist of short round rods of brass about ¼ inch in diameter and 3 inches long. The ends of the rods are filed down to sharp points which make the testing connections to the set. The rods are shrouded with ebonite insulation which terminates in handles which can be conveniently held whilst the test is conducted.

Fig. 10.—TESTING THE INSULATION RESISTANCE BETWEEN MAINS INPUT TERMINALS AND EARTH.
(See also Fig. 9.)

EBONITE, ITS NATURE AND WORKING

By EDWARD W. HOBBS

EBONITE is normally black in colour, even in texture, homogeneous, practically non-hygroscopic, is resistant to most acids and is an excellent electrical insulator.

During the manufacturing stages ebonite can be prepared and worked in various ways. It can be moulded during the plastic state, forced into dies and then vulcanised; the product is the exact converse of the shape of the die or mould, is homogeneous and may take almost any simple or complicated shape, hollow or solid.

Metallic parts, if embedded during the moulding stage, become immovably fixed during vulcanisation.

Practical Considerations

The successful working of ebonite and kindred materials, as well as the treatment or repair of broken parts, depends in no small degree upon an appreciation of the nature of the material and the processes to which it has been subjected, because they directly affect the method of working, and for this reason it is desirable to consider briefly some variations of ebonite.

When Buying Ebonite

When purchasing supplies always take care that the best quality is obtained, and, as it is impracticable for the worker to judge the nature of the compound, deal only with reputable manufacturers or obtain a branded article. Ebonite is obtainable in the form of sheet, rods, tubes and moulded sections.

Sawing and Cutting

The most convenient way of sawing or cutting up ebonite sheet is to make use of a band-saw, a small circular saw or a power-driven fretsaw. Very thin ebonite can be cut with strong scissors.

A fine-toothed saw should be used and be run at medium speed; a fair amount of " set " or clearance on the teeth is advisable, because ebonite has a tendency to clog and tear.

The sawyer must judge by results, but should use as rapid a feed as the saw will stand without choking; too slow a feed causes the ebonite to overheat and become sticky, too high a feed may accentuate the tendency for the material to flake or become unduly rough and to tear on the underside. When properly handled, the saw should cut with a clean crisp ripping sound, and the chips should throw clear of the saw cut.

Much the same remarks apply when a circular saw is used, particularly with regard to speed and feed.

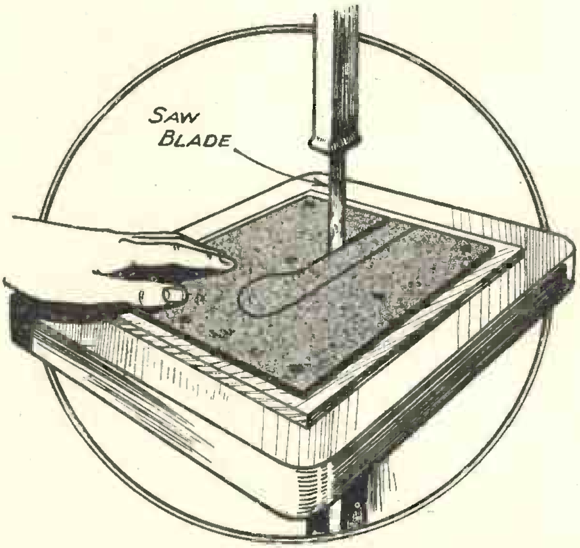


Fig. 1.—Backing up an Ebonite Sheet.

Thin wood is fastened under the ebonite to prevent the saw tearing the under surface.

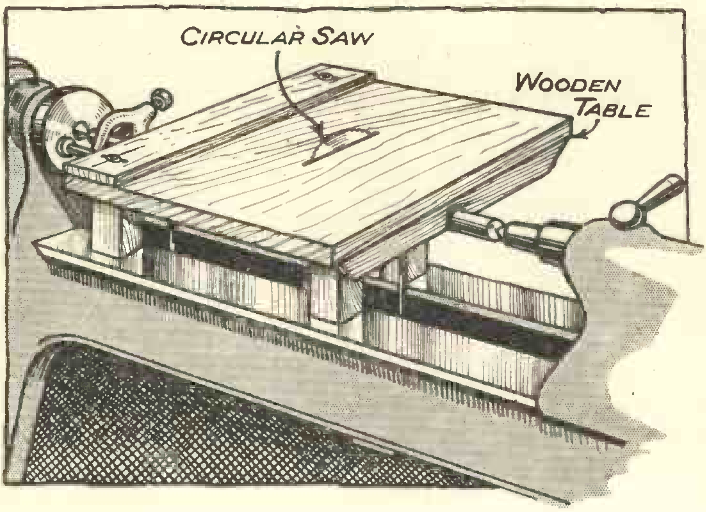


Fig. 2.—HOME-MADE SAW TABLE.

The construction of this simple but effective appliance is described in the text.

The ebonite must be held firmly to the backing, either by cramp pieces or by screws driven through waste parts of the material. Any relative motion between the ebonite and the backing will cause jambing and other troubles.

Sawing in the Lathe

When a band-saw or a circular saw is not available, much useful work can be done with the aid of any ordinary turning lathe. Some lathes are provided with a circular-saw attachment, and when this is the case use it as already described, but if such an appliance is not to hand an excellent substitute can be rigged up, as shown in Fig. 2, which indicates in semi-diagrammatic form all the essential requirements.

Mount the saw on a mandrel swung between centres and driven by a driver-plate and carrier in the usual way. A "metal slitting" saw, about 4 inches diameter, generally gives satisfactory service.

Next cut four uprights of wood about 2 inches square and of such length that they are about 1½ inches less than the distance between the lathe bed and the top of the saw.

Obtain a piece of smooth wood, about ⅞ inch thick, 9 inches wide and 12 to 15 inches long, and screw it to the tops of the four legs, spacing them so that they will stand squarely on the lathe bed. In the case of a lathe with a "V and flat" or "double V" bed,

Cutting Speeds

Hard and fast rules cannot be laid down for rates of feed and cutting speeds, for the reasons already given that various brands and kinds of ebonite vary in composition; the golden rules for success are to judge by the cut itself. If the material heats up unduly and emits an offensive smell (as it will!) either the saw speed is too low, the feed too rapid, or the tooth clearance is insufficient. Woodworkers should begin as if handling tough oak; metal workers may commence as if working on brass, then modifying their work accordingly.

Comparatively thick blocks or sheets of ebonite can be sawn without special preparation, but thin sheets should always be "backed up," that is, should be fastened temporarily to a thin piece of wood, as indicated in Fig. 1, which shows work in progress on a band-saw.

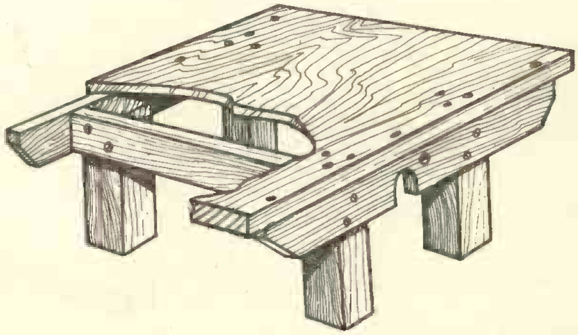


Fig. 3.—SEMI-SECTIONAL VIEW OF SAW TABLE.

This cut-away sketch shows essential constructional features of the table.

cut suitable notches in the ends of the legs before fixing the top. Complete the saw table by screwing battens from 2 to 3 inches wide and about ¾ inch thick to the legs and to the underside of the table, as shown in Fig. 3, notched to clear the mandrel, and cut a slit through the table top to clear the saw.

Clamp the table to the lathe bed with two L-shaped clamp bolts, as indicated in Fig. 5, modifying the details as may be necessary to suit the particular lathe.

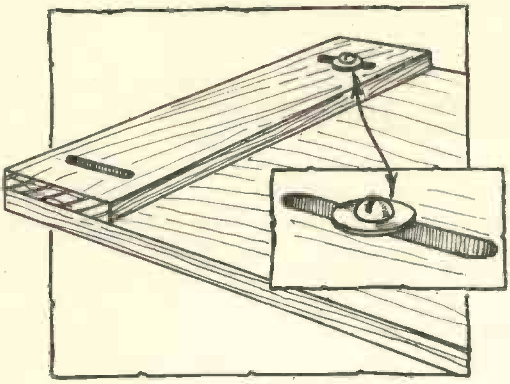


Fig. 4.—ADJUSTABLE FENCE.

Two screws hold the strip to the saw table, adjustment is provided by the slots which enable it to be moved sideways.

Guides and Fences

It is essential that the saw table be perfectly level and parallel with the lathe bed, also that it be quite rigid and that the saw projects about ½ inch or so above the table surface.

A simple adjustable fence or guide, consisting of a strip of smooth hard wood about ½ inch thick and 3 inches wide, should be prepared, as shown in Fig. 4, and screwed to the table with two round-headed screws and washers. Cut slots across the batten so that it can be moved parallel towards or away from the saw.

In use, the ebonite is laid on the table with one edge against the fence, the ebonite is then pressed forward against the saw and slightly sideways against the fence, thus removing a parallel strip. The fence is removed while cutting large sheets or wide pieces.

Cutting with Fret-saw

Special components for experimental wireless work can be sawn to shape with a powerful hand or treadle fretsaw. When a hand saw is used, fasten the work firmly in a vice, or upon the usual " cutting table," and manipulate the fretsaw in the normal way, but take exceptional care to keep the blade vertical and not to swing the saw frame suddenly or the blade will jamb and break.

Use fine - toothed wood-cutting saw blades, or, preferably, those made specially for metal sawing.

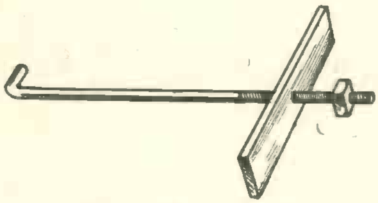


Fig. 5.—CLAMP BOLT.

This L-shaped bolt hooks into a hole in the saw table and is held down by a nut and plate beneath the lathe bed.

Use of Hack Saw

An ordinary hack saw and blade is quite suitable for sawing ebonite, but here again the great things are to regulate the cut and feed according to results and always to keep the blade upright, and working in a straight line —otherwise jambs and breakages will be annoyingly frequent.

Fig. 6.—PISTOL-GRIP HACK SAW.

This pattern is most suitable for cutting ebonite ; it provides excellent control of the blade.

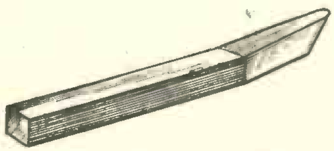


Fig. 7.—ROUND-NOSE LATHE TOOL.

A general purpose tool for turning ebonite in a lathe.

The most convenient type of hack saw frame is one with a "pistol grip" handle, as in Fig. 6; it enables a better control of the blade while cutting.

Turning Ebonite

Ebonite can be turned in the lathe in a similar manner to mild steel except that some special precautions should be exercised.

Turning tools for lathe work should be generally similar to those for turning mild steel, but they must be sharp and must have plenty of top rake and clearance.

A round-nosed tool, as in Fig. 7, is of general utility, but the edge must be kept perfectly keen by sharpening on an oil-stone; only a very sharp, keen tool will turn out good work.

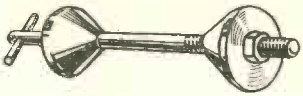


Fig. 8.—MANDREL FOR TURNING TUBES.

Hollow work, ribbed formers and the like can be chucked on this implement which is mounted between centres in the lathe.

Hand turning tools can be used as for brass turning, the lathe run at about the same speed as for that metal, but only light cuts should be taken.

On screw-cutting or surfacing lathes, set up the change wheels for a very fine feed, run the lathe as fast as possible but only take light cuts.

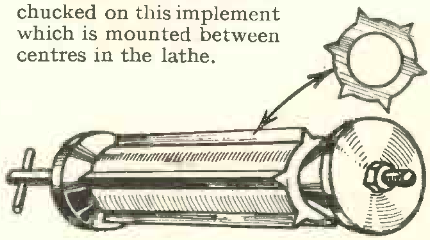


Fig. 9.—RIBBED FORMER MOUNTED ON MANDREL.

The work is held firmly between the conical ends and can then be turned in the lathe.

Should "chattering" occur, place a piece of thin leather packing around the lathe tool before tightening it up in the tool post. If this does not effect a cure it indicates that the method of chucking is at fault or that the work needs extra support.

Hollow work should be packed with wood wedged up firmly, but not so tightly as to endanger the ebonite.

Turning Ribbed Formers

Moulded ebonite coil formers, with V-shaped ridges along them, can best be turned if the ends are first turned up true and the former then mounted on a special mandrel.

The mandrel may be a piece of mild steel bar swung and driven as usual. It should be provided with two cone-shaped pieces of hard wood or metal, turned while in place on the mandrel, as shown in Fig. 8. One cone is fixed to the mandrel, the other is free to slide on it and the work is chucked between the two, as shown in Fig. 9; pressure being exerted on the slidable cone by means of a nut working on a screw thread on the mandrel.

Winding Grooves

Grooves or notches for the windings, especially those for short wave coils, can be cut on ribbed formers with a sharp V-shaped tool, using a very fine cut. The change wheels should be set for a pitch to suit the winding spacings, usually those for 16 threads per inch will be appropriate.

Ordinary screw threads can be cut in the lathe in the same way as for metal, but endeavour to produce the full depth of thread at one cut. Use soap and water or turpentine as a lubricant, and finish the work with a hand-chasing tool or by polishing.

Knurled Work

Knurling, or milled edges, can be worked on ebonite while in the lathe if the latter be run at slow speed and a knurling tool be mounted in the tool post of the slide rest. Apply pressure gradually with the top slide and lubricate the work with copious applications of soft soap and water.

Milling and Drilling

Ebonite can be machined in a milling machine with ordinary milling cutters, using soft soap solution as a lubricant.

Special shapes can be milled with a single fly cutter filed to shape from mild steel and very carefully sharpened on an oil-stone. It is not necessary to harden the steel in any way.

Drilling is carried out in the usual way, with a hand brace or a drilling machine. Specially made drills can be had and are useful if much work has to be undertaken, but for ordinary purposes the straight-fluted drills are the best to use, as they do not run or cause ragged edges to the same extent as a twist drill.

A rose-headed counter-sink or "frazee," as used by dental mechanics, should be used for counter-sinking the holes.

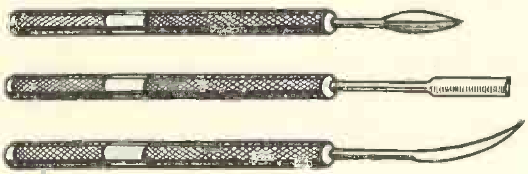


Fig. 10.—TOOLMAKERS' SCRAPERS.

These can be used in the same way as metal scrapers to impart a clean surface on ebonite, especially curved parts.

Screwing and Tapping

Ordinary wood screws can be driven direct into ebonite if a "tapping" size hole is drilled for it in the same way as if the hole were to be tapped for a metal screw.

An item to remember when screwing ebonite is that the threads have a tendency to finish up over-size, consequently use a size larger tapping drill than those specified for metal. Similarly, when machining for an external screw thread, make the material a shade undersize.

Another important point to watch when screwing or tapping with dies and taps is to work the tap (or die) gradually. Back it out frequently to clear the chips or there is grave risk of stripping the threads. Turpentine or soapy water should be used copiously as a lubricant.

Polishing

Ebonite is capable of taking a very high polish. Commence by cleaning the surface and graining it with finest emery paper; follow this by rubbing always in the same direction with a piece of clean but very worn fine emery paper, grade FF, not emery cloth. This results in a neat, smooth but slightly grained surface, which can be finished by smearing with lubricating oil—which restores the colour—and then polishing it dry with a soft cloth or an old chamois leather, but one that is quite free of grit or dust.

A superfine polish is attained by the use of very fine brick dust, or tripoli powder, applied slightly damp on a cloth rubber and used with a brisk but light circular motion. Finish off with a plain cloth rubber.

The best polishing can, however, only be done with a high-speed polishing mop run in a polishing head.

Rottenstone and oil is used for the first polishing and the finish obtained with a plain mop moistened with water. Do not keep polishing continuously but pause for a moment or two to allow the surface to cool.

Filing and Scraping

Little need be said about filing, it is done simply in the same way as if filing metal. The most useful grades of files are the "coarse," for roughing to shape, "second cuts," for general work, and "fine cut," for finishing.

Engineer's metal scrapers, such as the "tool makers" patterns shown in Fig. 10, are very useful for cleaning up awkward corners or for bevelling the edges. They should be worked with a clean stroke, as shown in Fig. 11, and are most effective on curved work.

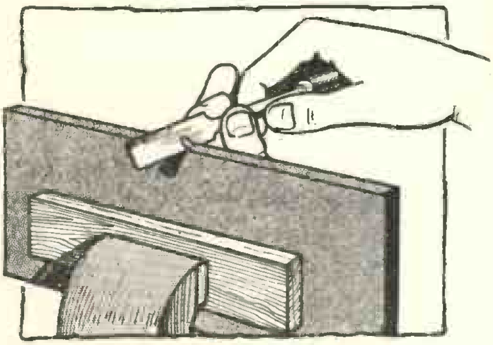


Fig. 11.—SCRAPER IN USE.

The tool is used with a long stroke to scrape off a shaving.

Bending and Straightening

Deformed sheets can be straightened or flattened by warming two smooth pieces of metal plate or even two pieces of stout flat wood, and then warming the ebonite in the steam from a kettle of boiling water until it begins to soften.

Immediately place it between the warm plates and leave it to cool and harden under gentle pressure.

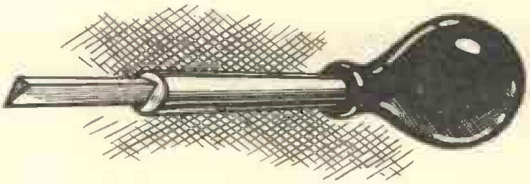


Fig. 12.—Engraving Tool.

This V-shaped tool serves as a burin, and with it figures or calibrations can be incised.

Similarly, rods or sheets can be bent to curved shapes by heating the ebonite in a steam jet, gently bending to the desired form and leaving to cool off.

Repair Work

Practically speaking, there is no way of permanently uniting broken pieces by means of adhesives. The best plan is to peg or dowel the parts or to screw them together.

Unwanted holes can, however, be screwed and plugged with ebonite and then cleaned off flush.

Surface cracks can be filled in by running a heated soldering iron over the surfaces beside the crack and then running on some more ebonite by melting a portion from a small strip of ebonite, much as if soldering on metal. When cold, the surface must be scraped and polished.

Engraving

Ebonite can easily be engraved either with the regular engraver's tools called the burin and graver, or with a sharp V-pointed steel, shaped as seen in Fig. 12, which is used by pressing the point down into the ebonite and then thrusting the tool in the desired direction. Straight lines should be engraved by running the tool alongside a steel straight edge.

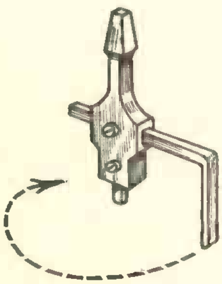


Fig. 13.—Expansion Bit.

With this drill bit large diameter holes can be cut with the aid of a brace.

Miscellaneous Hints

Marking out on ebonite for wireless work should be done with chalk, not with lead pencil. On fine work smear paste whiting over the surface, allow it to dry, then cut through it with a blunt scriber point, thus leaving clear black lines as a guide.

Use a sharp fine-pointed centre punch to indicate the centre of a hole and start the drill carefully in the depression so formed. Large diameter holes can be cut out with a carpenter's expansion bit rotated in a brace, as shown in Fig. 13; a pilot hole is drilled first in the centre to guide the bit.

Discs can be cut with a tubular-toothed drill, as shown in Fig. 14, the drill being filed to shape from steel tube and used with plenty of lubricant. The drill can be run in the lathe or in a large hand brace or drill press.

Moulded ebonite work is generally beyond the scope of the average wireless worker's equipment, but, in conclusion, it may be mentioned that special components can be made with "dental rubber," moulded and vulcanised in the same way as dentures are made.

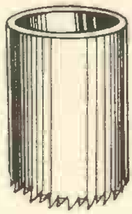


Fig. 14.—Toothed Tube Drill.

Fine teeth are filed on the end of a steel tube. The teeth are set in and out alternately.

Stated briefly, the procedure is to prepare a model or replica of the wanted piece in hard wax. This model is then embedded in moist plaster—arranged in two or more sections as required. When the plaster has hardened, the wax is melted out, the plaster moulds separated and the cavities filled with plastic rubber. The whole is then clamped in a metal vessel called a flask and vulcanised; when cold the flask is opened and the work removed, cleaned and polished.

MAKING A SHIP-MAST AERIAL

By EDWARD W. HOBBS, A.I.N.A.

SPECIAL features of the aerial mast shown in Fig. 1 are a shapely and nautical appearance, ability to remain upright, together with means for lowering the aerial and the top mast for cleaning or other attention. All these qualities are distinct improvements on the customary pole, which generally leans at an uncertain angle and is most slovenly in aspect.

Obviously, a ship mast can be made of any reasonable height, but for the average aerial in a small garden a height of about 35 feet is ample, and it is such a mast that is described in this article.

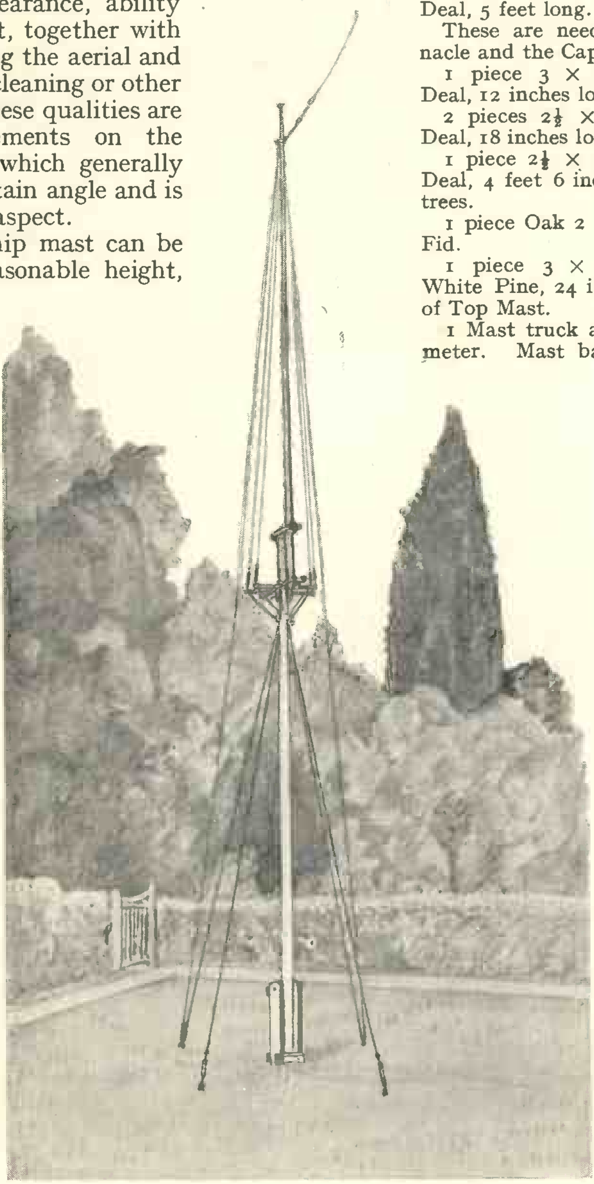


Fig. 1.—THE FINISHED AERIAL MAST.

Materials Required

The following is a list of all the materials for a 35-foot mast.

1 Straight scaffold pole, 18 feet long, 4 inches diameter at butt (bottom) and 3 inches diameter at top, or as near these sizes as may be obtainable locally.

1 piece of selected White Pine or Larch, $2\frac{1}{2}$ inches diameter, 18 feet long. This can be had ready prepared, that is, rounded or circular in section.

2 pieces 4 × 2 inches prepared Deal, 5 feet 6 inches long.

1 piece 4 × 2 inches prepared Deal, 5 feet long.

These are needed for the Tabernacle and the Cap.

1 piece 3 × 2 inches prepared Deal, 12 inches long, for the Hounds.

2 pieces $2\frac{1}{2}$ × $1\frac{1}{4}$ inch prepared Deal, 18 inches long for Trestle-trees.

1 piece $2\frac{1}{2}$ × $1\frac{1}{4}$ inches prepared Deal, 4 feet 6 inches long for Cross-trees.

1 piece Oak 2 × 1 × 6 inches for Fid.

1 piece 3 × 1 inches prepared White Pine, 24 inches long, for foot of Top Mast.

1 Mast truck about $2\frac{3}{4}$ inches diameter. Mast band, $1\frac{3}{4}$ inches diameter, with 4 eyes obtainable from marine store dealers. 1 metal sheaved aerial pulley; 1 side pulley; 10 turnbuckles or wire-strainers; 80 feet stranded galvanised wire $\frac{1}{4}$ inch diameter; 80 feet stranded galvanised wire $\frac{3}{16}$ inch diameter; and 80 feet of stranded galvanised wire $\frac{1}{8}$ inch diameter; 4 coach bolts $\frac{1}{2}$ inch diameter, 8 inches long, with nuts and washers; 1 ditto 10 inches long; 2 cleats; 1 piece of hoop iron 1 inch wide, 36 inches long; 1 large screw eye. All obtainable from any ironmonger.

1 knot of heavy sash line for aerial halliard; 1 knot of light sash line for flag halliard (if a flag is to be hoisted at the mast head).

1 cwt. of Portland cement, in a paper bag; 3 bushels sharp sand.

1 lb. tin of red-lead priming paint.

2 lb. tin white-lead finishing paint or 1 pint of Yacht Varnish.

In addition there will be needed a few screws and nails; 10 eye bolts, $\frac{5}{16}$-inch diameter and $3\frac{1}{2}$ to 4 inches long, with nuts and washers; 4 stakes each about 3 × 2 × 36 inches long; and about $\frac{1}{2}$ lb. No. 20 gauge copper wire.

For the aerial itself there will be needed the usual 100-foot length of stranded copper or phosphor bronze wire, a lead-in tube and 4 porcelain "egg" insulators, together with an eye bolt, chimney band or other suitable fixing for the house end of the aerial.

This may sound a formidable and expensive list, but actually the outlay is quite small, and is decidedly worth while when it is remembered that the resulting erection is efficient, permanent, and will last a lifetime.

Necessary Tools

Practically the only tools required are a brace and bits, hammer, spanner to tighten the nuts, smoothing plane, a handsaw, chisel, screwdriver, and a shovel or spade with which to mix the cement and make the concrete. No part of the work need cause any alarm even to an amateur worker.

The professional will realise that most of the constructional work can be carried out in the shop, leaving little more than an hour or so in which to erect the mast and tension the stays.

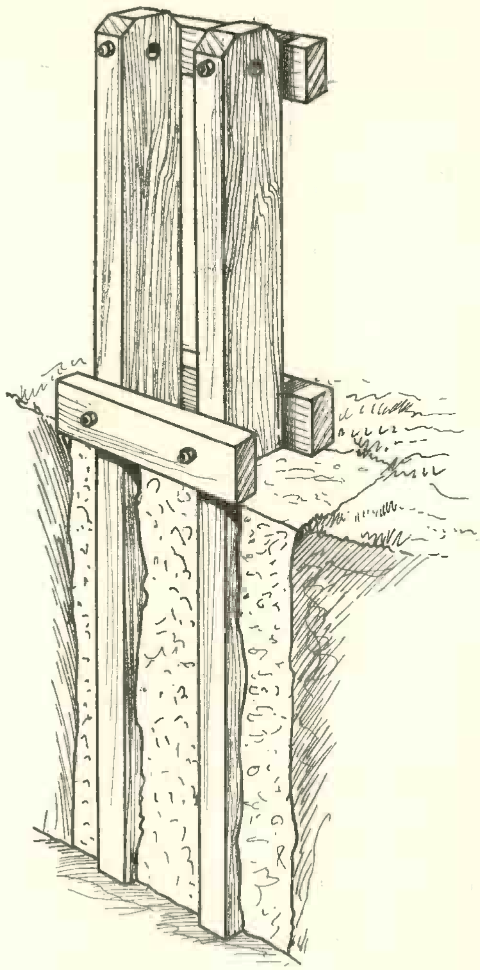


Fig. 2.—Details of the Tabernacle.

This rigid structure is bolted together, embedded in concrete and holds the bottom of the mast.

HOW THE MAST IS CONSTRUCTED

The mast consists of three elements: first the tabernacle, or lower part, which is embedded in concrete; secondly, the lower and top masts with the "top," that is the part which holds the topmast to the lower mast; and, thirdly, the rigging, which maintains the whole in an erect position.

Work should be begun on the scaffold pole or lower mast, as the exact diameter determines the width between the cheeks of the tabernacle and the spacing of the trestle-trees.

The First Thing to do

First plane a flat surface for a distance of 3 feet along one side of the pole, measured from the butt, then plane a similar flat on the opposite side, make each face about 1 inch wide and take care they are parallel. If necessary, saw the end off square and true, then drill a $\frac{1}{2}$-inch diameter hole square through the pole at a distance of 2 feet 3 inches from the bottom, and through the flats already formed on the pole.

Top of the Pole

Work at the top end of the pole consists in forming a square at the extreme end measuring $2\frac{1}{2}$ inches across the flats and

2 inches deep. Take care that the square is made with two opposite flats at right angles to the hole near the bottom.

Then at a distance of 14½ inches from the shoulders of the square form a flat on each side of the pole and at right angles to the bottom hole.

These flats should measure 2 inches wide and 6 inches deep. Their purpose is to afford a secure fixing for the hounds, or blocks, which support the trestle-trees.

Building up the Tabernacle

The tabernacle (Fig. 2) is the short rigid structure which is embedded in concrete in the ground and to which the bottom of the pole is bolted.

It consists of two parallel uprights, each measuring 5 feet to 6 feet in length, 4 inches wide and 2 inches thick. On sandy soils the length should be increased by 12 to 15 inches, but on very heavy soils the length may be reduced by 12 inches or so.

The general arrangements are clearly shown in Fig. 2, which being partly in section shows the lower portions of the uprights embedded in the concrete and the manner in which the three cross bars of 4 × 2 inch wood are bolted in place. The width between the uprights should be approximately 4 inches, but actually must be about ½ inch more than the width across the flats on the scaffold pole.

The cross bars are bolted on as shown, and holes are drilled near the tops of the uprights for the bolt which passes through the pole, as shown in Fig. 3.

Mixing the Concrete

Concrete used for setting the tabernacle may consist of 1 part by bulk Portland cement, 2 parts sharp sand and 2 parts broken brick, gravel, or other hard aggregate not larger than 2-inch diameter, the whole well mixed in the dry state, then moistened with water, so that a mass of the concrete when grasped in the hand shows a tendency to bind together.

Setting the Tabernacle in the Concrete

Dig as small a hole in the ground as possible to accommodate the legs of the tabernacle, keep the sides of the hole firm and vertical, then set the tabernacle upright in it, testing it with a plumb-bob; then deposit the concrete in the hole and ram it firmly down to consolidate it thoroughly. If possible allow a day or two to elapse before erecting the mast, but if speed is essential use a good brand of quick-setting cement which will set in a few minutes and harden the same day.

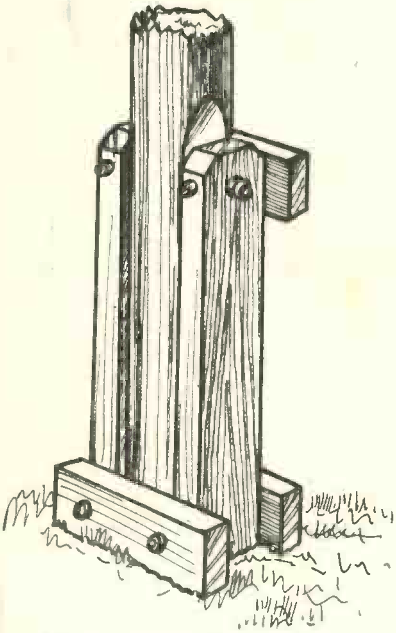


Fig. 3.—Lower End of Mast. Shown in place in the tabernacle.

Making the Top

The top consists of the hounds, trestle-trees and cross-trees with their fitments. Begin by making the hounds, as shown in place in Fig. 4—they are tapered blocks 6 × 3 × 2 inches, square at the tops and tapered towards the bottom. Securely nail or screw them to the flats already formed on the pole, then place the trestle-trees—which are 18 inches long, 2½ inches deep and 1¼ inch wide—on the top square faces of the hounds; set them square with each other and at right angles to the axis of the pole. Screw or nail them to the pole and to the hounds, then cut shallow notches 1¼ × ¾ inch for the cross-trees, which are the same sizes as the trestle-trees but stand at right angles to the latter and are likewise screwed or nailed to the pole. On the front side of the pole fix a block of 3 × 2 inch wood between the trestle-trees so as to leave a space 3 inches square immediately in front of the front cross-tree as shown in Fig. 6, and screw the screw eye into the front face.

This square hole—called the fid hole—is for the foot or bottom of the top mast to fit into.

Now drill a ½-inch diameter hole through the scaffold pole at a distance of 12 inches from the bottom of the hounds and exactly in line with them.

Drive a hardwood peg through this hole, leaving 1 inch projecting on each side. Oak is the best wood for this purpose.

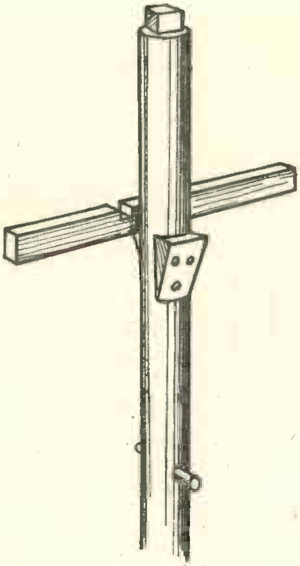


Fig. 4.—MAKING THE TOP.

The hounds and one trestle tree are shown in place ; also the square end.

Making the Cap

The cap is the part which fits on the squared end of the mast and grasps the top mast, and is shown complete in Fig. 5. It is merely a piece of 4 × 2-inch wood 9 inches long, with a 2½-inch square hole near one end and a 2½-inch diameter hole near the other end. The exact centres of these holes should correspond with that of the centre of the mast and the centre of the fid hole, which is approximately 4 inches. The outer edge of the cap should be bound with hoop iron securely fixed with clout nails or round-headed screws.

The cap should fit tightly on to the squared end of the mast and may be fixed with thin wedges driven firmly into the joint.

Complete the work on the top, as shown in Figs. 5 and 9, by screwing the flat pulley on to the front of the mast, just beneath the cap, and fix an eye bolt to the end of each cross-tree, four in all.

Shaping the Top Mast

The foot of the top mast should be built up and shaped as shown in Fig. 7, by glueing and screwing four pieces of wood to flats formed about 6 inches above the bottom. The whole purpose is to make a square portion which will fit nicely into the fid hole and leave a part projecting downwards. This projecting part should be slotted at right angles and have a plain sheave or pulley fitted into it. At a distance of 3½ inches from the bottom of the square part cut a mortise, at right angles to the slotted end, making the mortise 2 inches deep and 1 inch wide. Prepare and fit an oak key—called the fid—to fit nicely, but not too tightly, in this hole, and leave 1½ inches projecting at each side.

The lower 3 feet of the pole should be left plain, but from this point to 12 inches from the top plane the pole to a taper, so that at the upper end it will be only 1¾ inches diameter, then taper the remainder to finish only 1 inch diameter, where the truck seen in Fig. 8 should be fixed.

Fit the mast band at a distance of 12 inches from the top end, but do not fasten it.

Next paint or varnish the woodwork and give the metal work a coat of black Japan or other suitable enamel.

Preparing the Rigging

Much of the rigging work can be done before the mast is set up. Begin by cutting the thick wire into two equal lengths, then double over each piece in the middle, pass the two ends over the back cross-tree so that the loop comes on the front side of the mast, then cross them under the trestle-trees and bind the place where they cross with copper wire, as shown in Fig. 9.

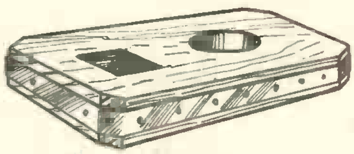


Fig. 5.—THE MAST CAP.

The cap is bound with hoop iron, and is fixed to the top of the lower mast.

Put on the second piece of wire in a similar manner, but in the reverse direction, so that the loop is on the back of the mast and the ends at the front.

Temporarily attach a turnbuckle to the ends of the wires, then coil them neatly and tie them up to prevent them becoming tangled.

Cut the next thickest length of wire into two and double them in

Fig. 7.—Foot of Top Mast.

The lower end is slotted for a sheave, and above it the pole is built up to a square shape. The mortise hole is for the fid or oak key which holds the mast in place on the top.

the middle as before, but put one end only through one eye of the mast band and bind together the two parts with copper wire, just below the eye.

Put the second wire into the eye on the mast band diametrally opposite the first and bind as before.

Double over the whole length of thin wire and

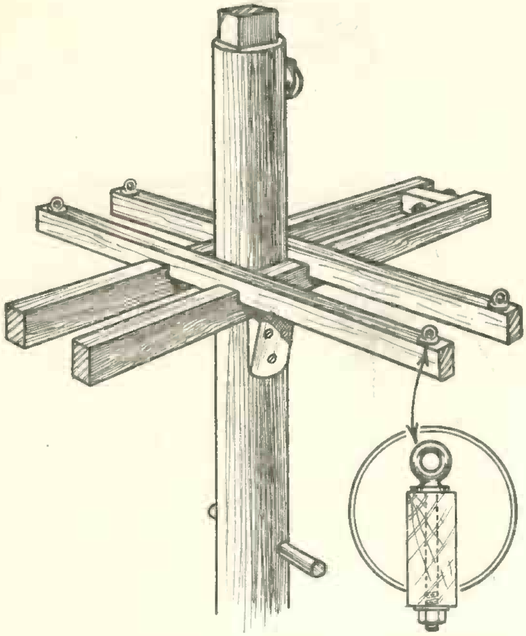


Fig. 6.—Details of the Top.

Here is shown the top complete with the eye-bolts in place in the cross-trees.

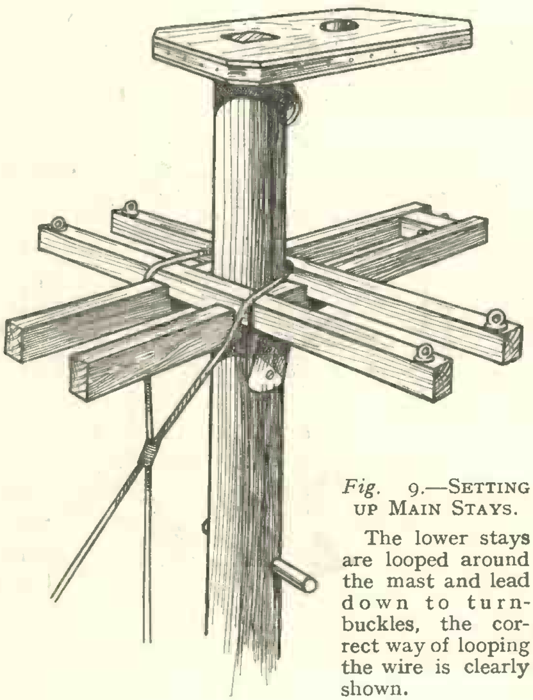


Fig. 9.—Setting up Main Stays.

The lower stays are looped around the mast and lead down to turn-buckles, the correct way of looping the wire is clearly shown.

similarly fix it to the back eye on the mast band, then fix the aerial pulley to the remaining eye, as in Fig. 10, and pass the aerial halliard—or rope—

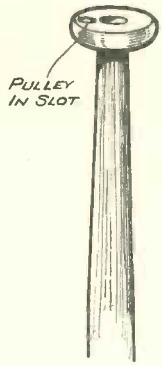


Fig. 8.—Mast Truck.

Fixed to the top mast as a finial and to carry the sheave for a flag.

through the pulley.

Inserting the Top Mast

If space permits lay the mast on the ground and put the top mast into its place by sliding it upwards through the fid hole and the hole in the cap and keep it in place by putting the fid into its mortise. Then adjust the lengths of the top mast stays and fix the ends to turn-buckles by means of an eye-splice or by doubling and very securely binding — or whipping—with copper wire.

The mast band must be a dead tight fit on the mast, and should it appear to be at all slack insert a band of leather—such as a short length of strap — and drive the mast band on to it.

The Futtock Shrouds

These are short pieces of the same wire as used for the top-mast stays, and they are fixed from the eye bolts on the cross-trees to the mast and held down by the oak peg, as shown in Fig. 11. To fit them, form an eye by splicing or looping and whipping and slip it over an eye bolt on the cross-tree, then take the wire down, round the mast, under the peg on the opposite side of the mast, and up to the eye bolt on the next cross-tree on the same side as it started.

Slacken the wire, then form an eye at the required place and slip it over the eye bolt. Lever the wire back into place and fit a stay to the other cross trees in a similar manner. Tighten these wires by seizing them together with copper wire drawn up very tightly and securely fastened. Fix one end of the mast rope to the screw eye on cross-trees, loop it under the sheave on foot of top-mast and reeve it through the flat pulley on mast.

Fix the truck to the top of the top mast, put flag halliards through the sheave (if desired), then proceed to erect the mast.

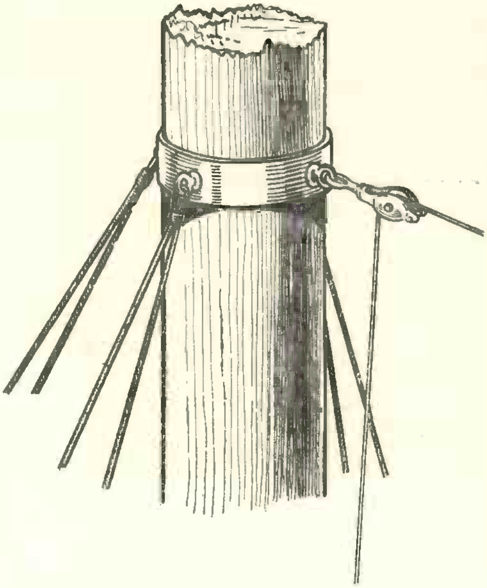


Fig. 10.—MAST BAND IN PLACE.

The top mast stays and backstays are secured to three of the eyes—the aerial pulley to the fourth eye.

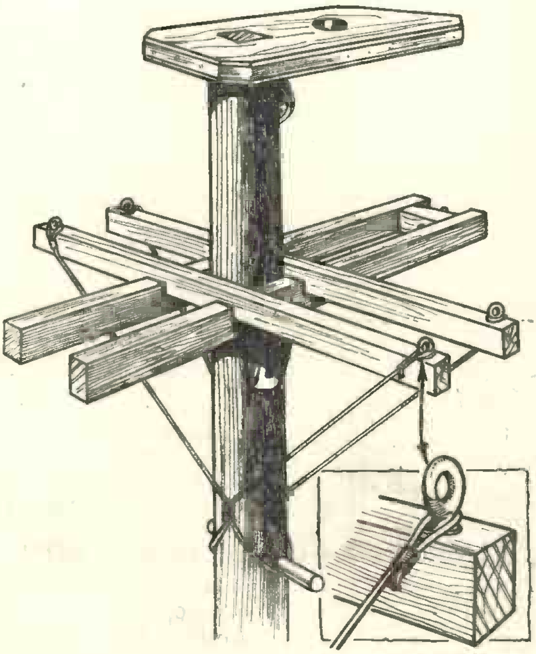


Fig. 11.—RIGGING OF FUTTOCK SHROUDS.

These relieve the cross-trees of the pull of the top mast stays.

Erecting the Mast

To erect the mast, unship the top mast and lay it aside, then lay the lower mast on the ground with its foot in the tabernacle; lift up the mast until the foot gets a grip between the two cross bars at the bottom of the tabernacle, then haul it and push it up into position, using the wire stays for this purpose.

If necessary, wedge up the foot of the mast until the bolt can be driven through the tabernacle and the mast.

Next attach the stays to turnbuckles fixed to eye bolts in stout stakes

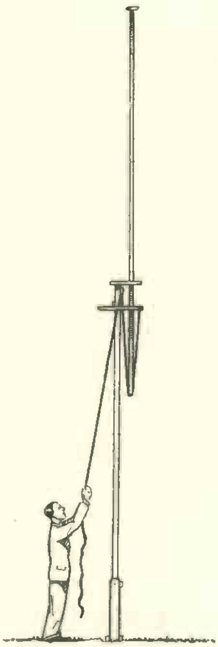


Fig. 12.—How the Top Mast is Raised.

This diagram shows the arrangement of the top mast rope and how by hauling on it the mast is raised.

driven at an angle into the ground about 4 feet away from the mast and tension the wires slightly. Plumb the mast and get it true, adjusting as necessary by tightening or slackening the stays until all are evenly tensioned.

Next place the top mast through the fid hole, place the top mast rope under the sheave and haul up for a foot or so, as shown in Fig. 12—sufficient to enable the mast band and stays to be replaced. Then haul up and secure the top mast with the fid as before and set it up true, and plumb by adjusting the stays and backstays, all arranged as shown in Fig. 13.

Fitting the Aerial

These are quite sufficient to hold the mast, but to counteract the pull of the aerial wire the two backstays should be fixed to the stakes at the back of the mast and be tightened up sufficiently. The mast can safely be climbed to the top from which position the top-mast stays can be adjusted and the aerial fitted and hauled into place. Any type of aerial can be used in the customary manner.

It may possibly seem from the foregoing that a great deal of time and trouble is involved in making and erecting this mast, but actually it can be done in a few hours; the work is simple and straightforward and the cost extremely moderate for a durable and pleasing article.

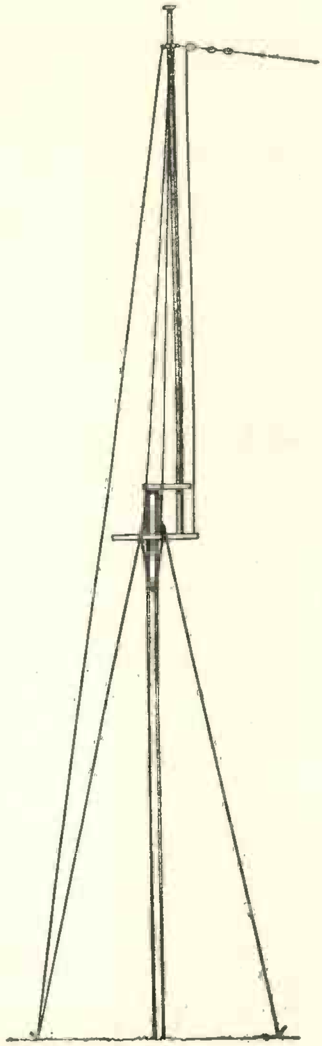


Fig. 13.—Arrangement of Rigging.

Here is shown the whole of the rigging in place.

Fig. 14.—The Complete Aerial Fitted Up.

The Finished Aerial

As will be seen from Fig. 14, which shows the complete aerial fitted up, it is well worth taking a little trouble to obtain a really neat looking job.

A later article will deal fully with the advantages of different types of aerials.

THE EXPERIMENTER'S CABINET

By HERBERT H. DOWSETT

THE experimenter's cabinet, the construction of which is described in the following article, is an accessory which every enthusiastic amateur set-builder should possess. Whilst giving a really finished appearance to any set, it offers immediate access to any individual part for adjustment or alteration, and in less than half a minute the set can be removed entirely from the cabinet without it being necessary to disconnect the leads to batteries, etc.

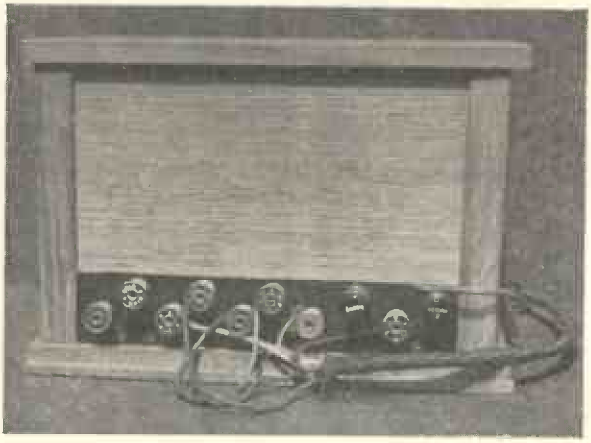


Fig. 1.—THE COMPLETED CABINET.

If the experimenter cares to standardise the size of the front panel, baseboard and terminal strip, he can have several sets made up at once, any of which can be placed in the cabinet when in use.

Materials Required

Fig. 2 shows sections through four stock mouldings which can be purchased in several sizes from almost any timber merchant. This should not be less than 1 inch square and must be a hardwood such as oak or mahogany.

This moulding, unfortunately, differs considerably in the position, depth and width of the grooves, and it is therefore impossible to lay down any hard and fast measurements for a particular size of panel, the only detail of importance being that the grooves should be a trifle wider than the thickness of the front panel. In a majority of cases this will be just over $\frac{3}{16}$ in., as this is the most popular size of vulcanite used in set construction.

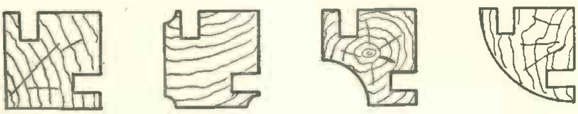


Fig. 2.—SECTIONS THROUGH TYPICAL MOULDINGS.

Any one of these will be found suitable for the side supports.

Four pieces of this moulding are required, each piece being $\frac{3}{4}$ inch longer than the height of the front panel of the set.

The base of the cabinet, which should also be of hardwood, must be $\frac{3}{4}$ inch thick to allow for firm fixing of the corner posts. The top should be of the same material.

The loose panels can be of wood or vulcanite, the latter, now supplied in various figured surfaces, giving an exceptionally fine appearance to the finished cabinet.

HOW TO CONSTRUCT THE CABINET

The corner mouldings are first prepared. Mark off $\frac{3}{4}$ inch from one end, and with a saw cut away the sections marked " A " and " B " in Fig. 4, the dotted lines indicating the positions of the four cuts necessary. This leaves a square section $\frac{3}{4}$ inch long, shown in Fig. 5, which is let into the base of the cabinet in the following manner.

Fig. 3.—Testing the Posts with a Square after Glueing.

Fixing the Four Corner Mouldings in Position

Set out on the base the exact positions for the four corner mouldings. There are two methods of cutting the square hole. It can be cut out with a fretsaw, which is rather a long job unless a machine saw is available. The second method is to select a drill, the diameter of which is equal to one side of the square, and drill a circular hole first, then clearing away to the corners with the aid of a sharp chisel. Fig. 6 shows one corner of the base with a corner post ready for insertion.

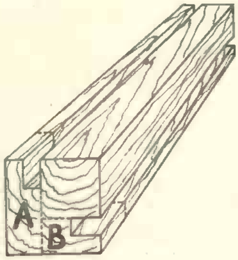


Fig. 4. — Preparing the Corner Mouldings.
The sections marked A and B are sawn away.

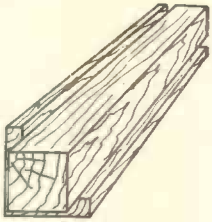


Fig. 5.—The Corner Mouldings Ready for Inserting into Base of Cabinet.

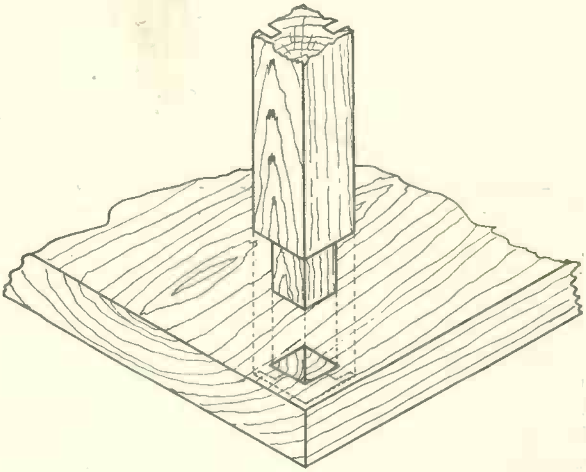


Fig. 6.—A Corner of the Base.
With corner post ready for insertion.

Glueing the Posts in Position

When all four corners have been prepared, the posts should be glued into position and carefully squared in both directions to ensure their being vertical. They should then be left until the glue is quite hard. Fig. 7 shows the four posts in position.

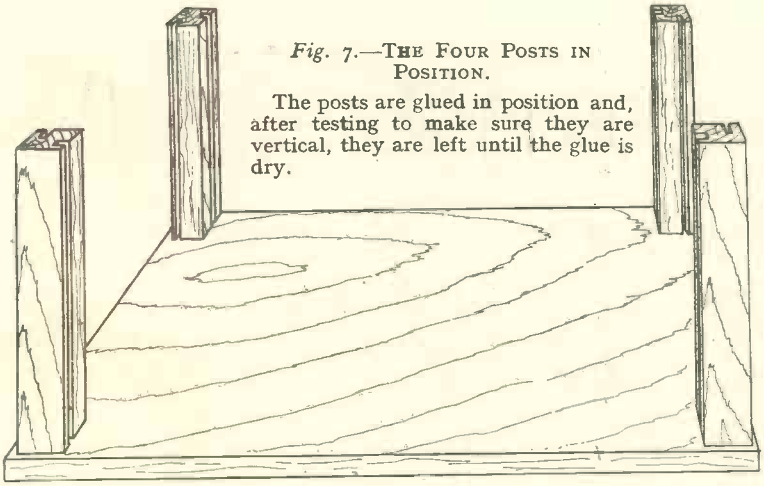


Fig. 7.—The Four Posts in Position.
The posts are glued in position and, after testing to make sure they are vertical, they are left until the glue is dry.

How Rigidity is Obtained

Fig. 9 is a plan of the cabinet, and it will be noticed that the front panel and terminal strip overlap the baseboard of the set by the depth of the grooves in the corner moulding. This permits of the set being free to lift out of the cabinet, at the same time ensuring a reasonable degree of rigidity when the set is in use. The loose panel for the back of the set is cut narrower than the end panels to allow the terminal strip to occupy the same groove. A glance at one of the accompanying photographs explains this fully.

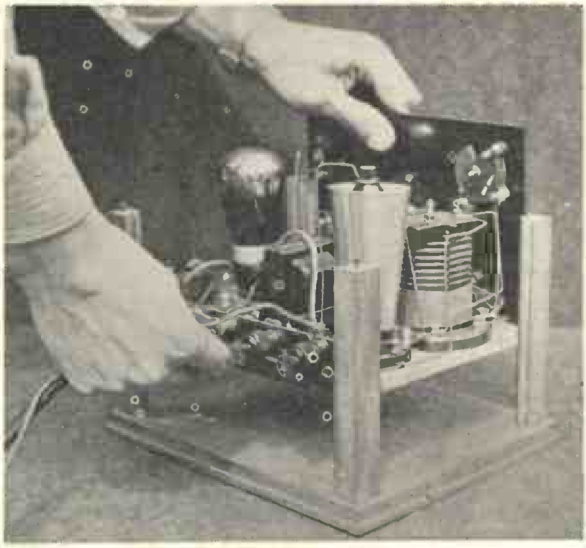


Fig. 8.—Inserting the Receiver into the Cabinet.

How the Top is fitted

The top is fitted by means of four pins, one in the top of each corner post, these pins fitting into holes drilled partially through the top to correspond with them. The pins are formed by driving a screw into the top of each corner post and cutting off the head with a hacksaw, leaving ½ inch of the screw standing out from the top of the post.

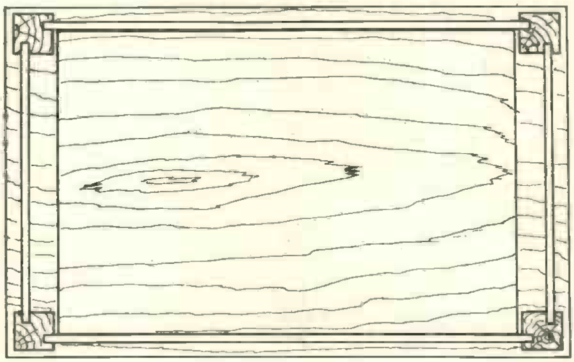


Fig. 9. — Plan of the Cabinet.

The front panel and terminal strip overlap the baseboard of the set by the depth of the grooves in the corner moulding.

Staining the Loose Panels

If the loose panels are of the same wood as the remainder of the cabinet, it is a good plan to stain them a different shade before polishing, as the contrast is very pleasing and adds considerably to the appearance of the finished job.

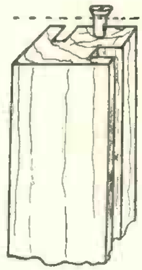


Fig. 11.—How the Top is fitted.

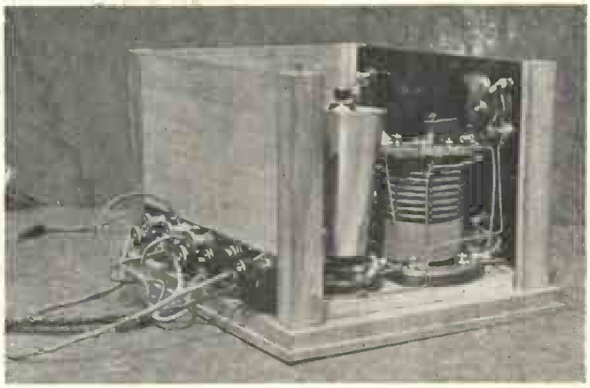


Fig. 10.—This shows how the Loose Panels are Slid into the Grooves.

SERVICING

NOTES ON THE PYE RADIOGRAMOPHONE, AND THE "MM," "Q," AND OTHER RECEIVER MODELS

THE PYE RADIO-GRAMOPHONE

WHEN trouble is experienced with the radiogramophone, the following tests should be made :—

(1) Confirm that the connection to the loud speaker, pick-up, aerial, earth and mains, are satisfactory.

(2) The valves should be tested, if suitable apparatus is available, or replaced with a set known to be satisfactory and the voltages taken between the chassis and the following points :—

(Note that a high resistance voltmeter (1,000 ohms per volt) should be used and an insulated prod is necessary to make contact with the first screened-grid valve.)

Fig. 1.—THE PYE RADIOGRAMOPHONE.

An example of the latest design and construction to facilitate service adjustments for the retailer.

Removal of the Gramophone Motor

When removing the motor great care should be taken not to disarrange the motor board suspension material.

(1) Remove turntable.

(2) Release mains lead and earth wire from motor.

(3) Remove the four bolts with locking nuts which hold the motor to motor-board.

The motor can now be lifted out of the cabinet.

Modulation Hum

On some mains supplies, when receiving a radio transmission, a "modulation hum" is experienced. The hum will be tuneable, that is, it will only be evident when the receiver is tuned to the carrier wave of a transmitting station.

To cure, connect across the H.T. secondary winding of the mains transformer a ·005 mfd. fixed condenser (1,000 volt D.C. test). The H.T. secondary leads from the transformer are pink and black with white tracer.

The condenser should be mounted on the chassis below the mains transformer, a lead taken from the condenser to the pink transformer lead. The other condenser terminal to the transformer black lead with white tracer.

Values of Resistances and Capacities

RESISTANCES (see Fig. 7).

R2, 33 ohms ; R3, 20,000 ohms ; R4, 3,000 ohms ; R6, 20,000 ohms ; R7, 10,000 ohms R8, 10,000 ohms ; R9, 10,000 ohms ; R10,

·25 megohms; R11, 15,000 ohms; R12, ·25 megohms; R13, ·1 megohms; R14, ·1 megohms; R15, 2,000 ohms; R16, 106 ohms; R17: In units of 7,000 ohms, 23,000 ohms, 13,000 ohms, 30 ohms, 170 ohms, 170 ohms; R19, 2,000 ohms; R20, 25,000 ohms; R21, 2,000 ohms; R21A, 170 ohms; R22, 170 ohms; R23, 30 ohms; R24: 13,000 ohms in 2 units, 10,000 ohms and 3,000 ohms; R25: 23,000 ohms in 3 units, 2 of 10,000 ohms, 3,000 ohms; R26, 7,000 ohms.

CAPACITIES

C1, 10 mfd.; C2, ·5 mfd.; C3, C25 and C26, ganged variable condensers; C4, C24 and C8, Trimmer condensers; C5, ·5 mfd.; C6, 10 mfd.; C7, ·0001 mfd.; C9, ·0001 mfd.; C10, 3 mfd.; C11, ·002 mfd.; C12, ·002 mfd.; C13, ·002 mfd.; C14, 2 mfd.; C15, 1 mfd.; C16, ·5 mfd.; C17, 2 mfd.; C18, 1 mfd.; C19, 8 mfd.; C20, 4 mfd.; C21, 4 mfd.; C22, 1 mfd.; C23, 10 mfd.; C27, 1 mfd.; C28, ·025 mfd.

R5 and R17 are two mechanically coupled variable resistances.

Testing Anode Circuits

Valves should be tested if suitable apparatus is available, or they should be replaced with a set known to be satisfactory and the voltages taken between the chassis and the folowing points:

(1) First S.G. valve, plate 144 volts, screen 52 volts.

(2) Second H.F. valve, plate 172 volts, screen 52 volts.

(3) Detector valves plate, 140 volts on radio, 150 volts on gramophone.

(4) Pentode valve, plate 250 volts.

(5) Pentode auxiliary grid, 200 volts.

These tests will show either: (*a*) all voltages within plus or minus 10 per cent.; or (*b*) one or more circuits incorrect. In case (*a*) the power pack and anode circuit components are O.K. and the trouble must be sought elsewhere. In case (*b*) should all voltages be low test the power pack components, but if only individual circuits are low, test their associated components.

Fig. 2.—REMOVING THE CHASSIS.

1. Remove the motor earthing lead from the chassis. 2. Detach the mains lead from the motor, and carefully insulate the end wires with insulating tape.

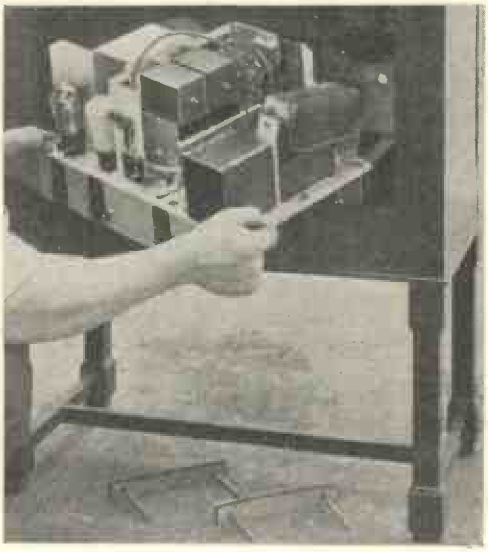


Fig. 3.—REMOVING THE CHASSIS.

Release the loud speaker and pick-up leads from the chassis.

Checking the Power Pack

The voltages should be checked as below, the Mains Transformer secondaries with an A.C. voltmeter, and the rectified voltages with a high resistance D.C. voltmeter.

Heater—3·9 volts R.M.S.

H.T. Secondary—185 volts R.M.S.

Rectified output 310 volts D.C.

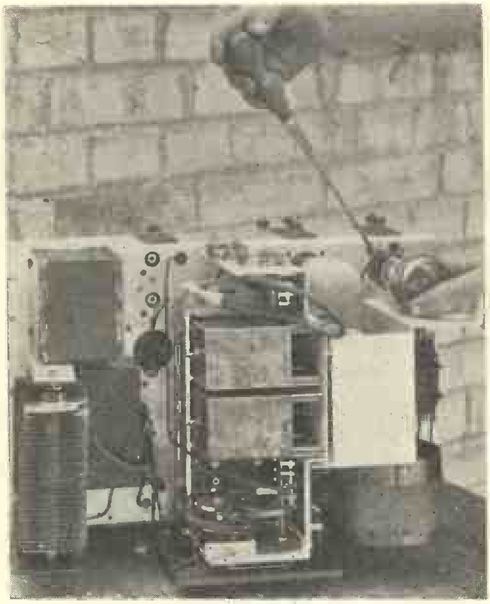


Fig. 4.—Withdrawing the Valves.

These should be gently levered out with the aid of a screwdriver.

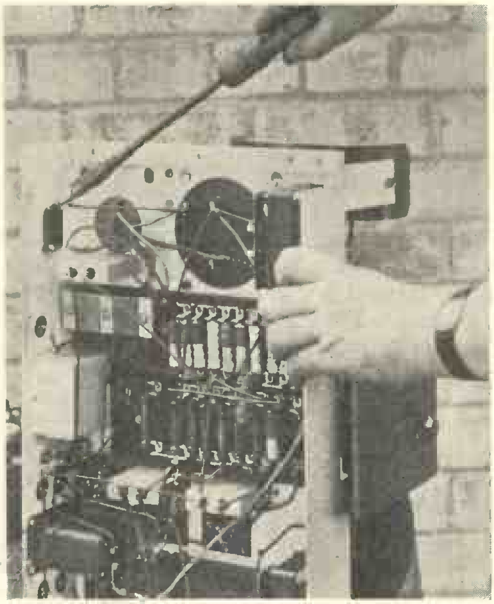


Fig. 5.—Unsoldering the Fixed Condenser for Preventing Modulation Hum.

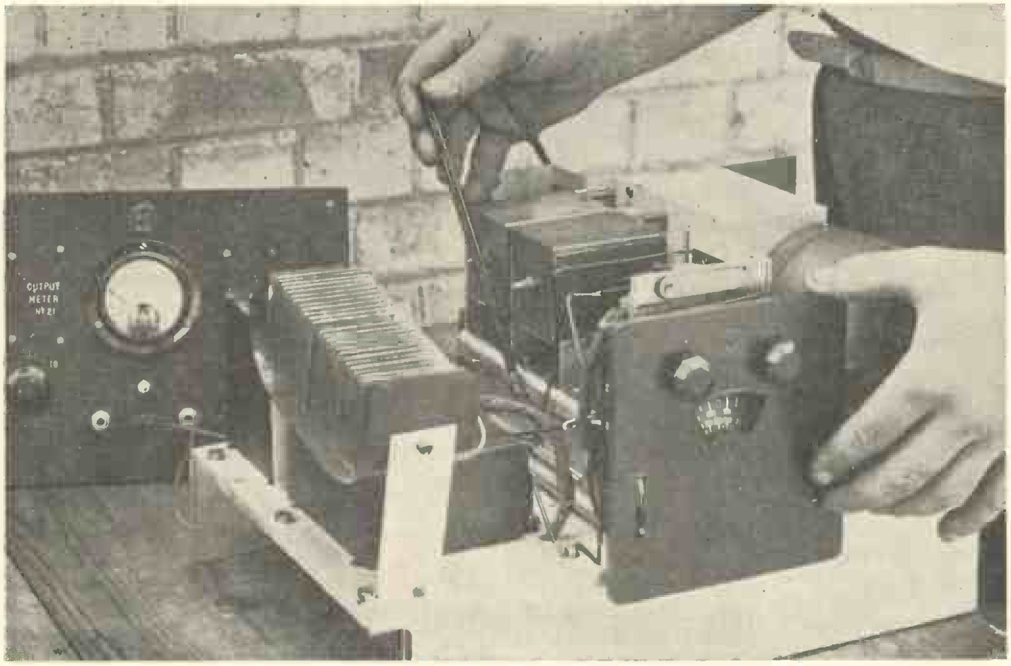


Fig. 6.—Adjusting the Trimming Condensers.

This is done with a special ebonite rod as shown in the photograph.

Voltage across potential divider R.17–275 volts.

Low readings may be due to a faulty component in the power pack or in the receiver.

The total D.C. current should be taken by inserting a milliammeter in the lead between the smoothing choke and the positive end of the potential divider and a reading of approximately 52 m/a should be obtained. An excessive reading here will suggest a short in the receiver, while a low reading will suggest a broken circuit or faulty power pack.

Circuit	Associated Components
Detector valve.	Bias resistance R12, R13, R18, switch and condenser C17, C9.
Pentode valve.	Intervalve transformer T1, resistance R10.

The units of the potential divider, R17, should be checked.

THE PYE "MM" RECEIVER

When locating a fault, the condition of the valves should first be tested either by checking their characteristics if suitable

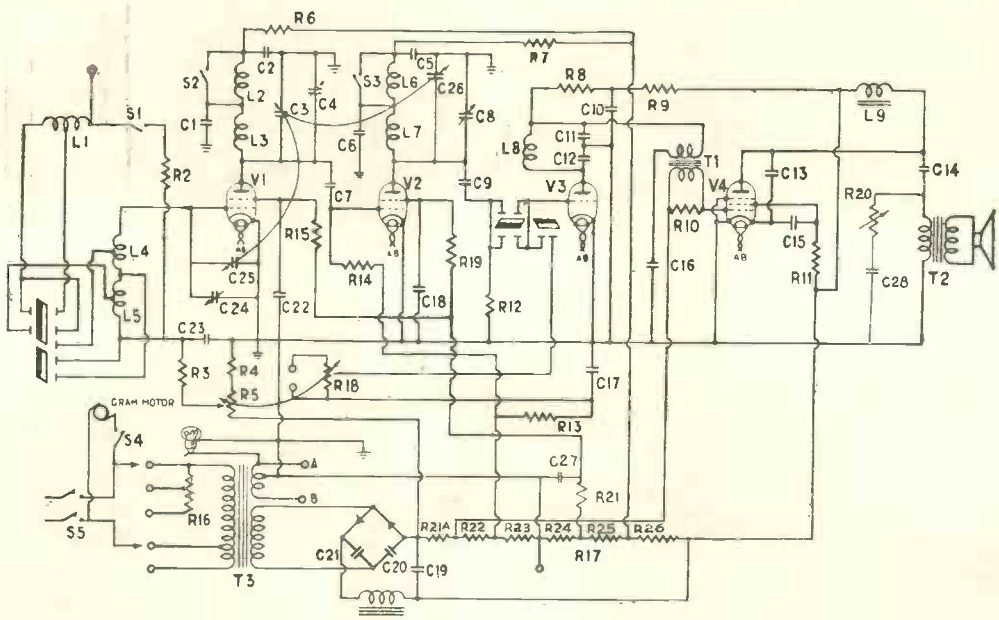


Fig. 7.—Theoretical Diagram of Pye Radiogramophone.

Testing Grid Circuits

If the voltages at the anodes of the valves are correct and the resistances in the anode and grid circuits (including the potential divided unit resistances) are accurate, it can be safely assumed that the valves are correctly biased.

Circuit	Associated Components
First screen-grid valve.	Bias resistances R3, R4, R5, condenser C23, coils L4 and L5 switch, variable condenser C24 and C25.
Second screen-grid valve.	Bias resistance R14, condenser C7.

apparatus is available or by replacing with a complete set of valves known to be satisfactory. Next, the voltages at the valves should be checked in accordance with details given for testing anode circuits on Page 155. If this shows :—

(*a*) All voltages proportionately low—check the voltages in the mains unit ;

(*b*) All voltages normal, or one circuit or more of low voltage—check the chassis (see later).

Replacement of Condenser Bank

To remove the condenser bank, the wires should be unsoldered and the four

Fig. 8.—Removing the Back of the Pye "M.M." Model.

This can be done with a coin as shown. The bakelite plate of the main switch is then removed from the cabinet by taking out its two screws.

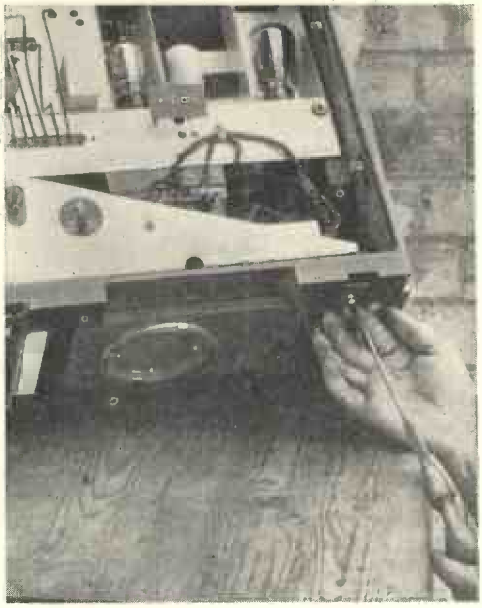


Fig. 9.—Removal of "M.M." Mains Base.

The four fixing screws which fasten the mains unit to the cabinet are removed from the base.

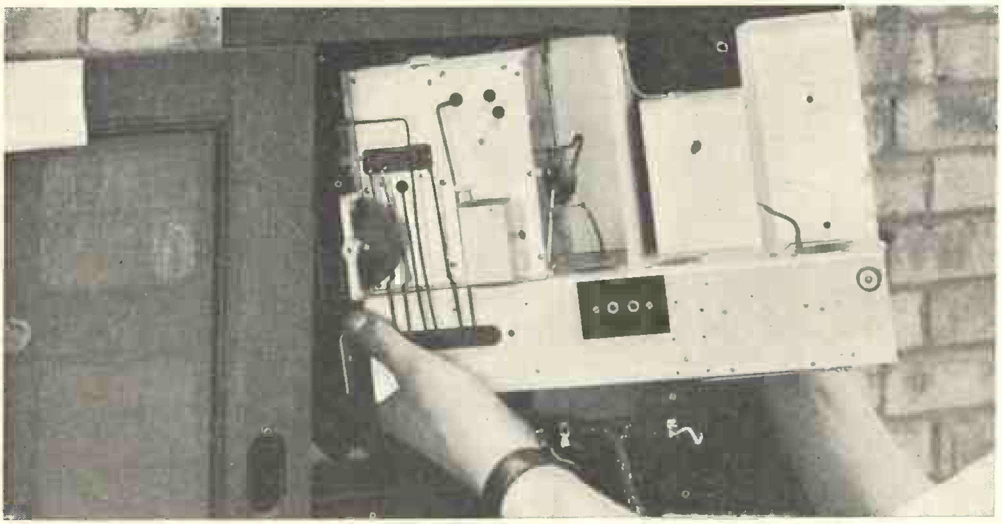


Fig. 10.—Withdrawing the Chassis.

This can be done after unsoldering (*a*) six leads from bank condenser in mains unit, (*b*) four leads from bakelite contact strip situated below valve platform, and removing mains unit, (*c*) three frame aerial connections from contact strip at the bottom left-hand corner. The following screws and nuts are then removed : (*a*) one screw in top interior of cabinet (A in Fig. 15), (*b*) screws on extreme right of metal baseplate (B in Fig. 15), leaving rubber washers in position ; (*c*) two nuts on extreme left beneath tuning control panel (C in Fig. 15). Withdraw right-hand side first.

Fig. 11.—REMOVAL OF THE MAINS UNIT (*see also* Figure 9).

The voltages can, however, be measured without unsoldering the wire. The unit should be withdrawn from the cabinet as far as the wires will allow after removing the four retaining screws.

Fig. 12.—TIGHTENING THE LOUD SPEAKER BAFFLE.

The loud speaker is a low resistance moving-coil mains energised type. Field winding resistance, 2,500 ohms, output transformer primary 650 ohms, secondary ·2 ohms, speaker coil resistance 1·23 ohms.

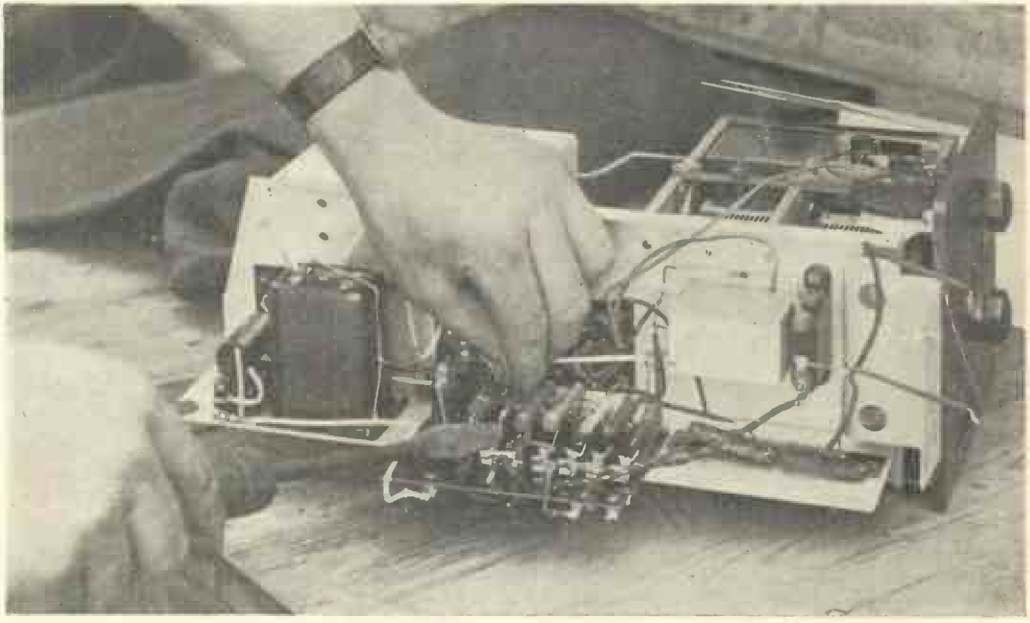
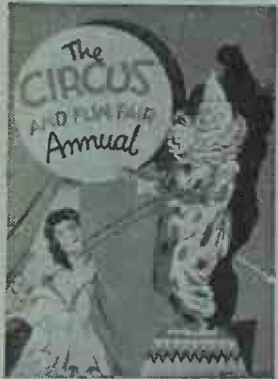


Fig. 13.—REPLACING THE DECOUPLING RESISTANCE.

CHILDREN'S ANNUALS FOR 1933

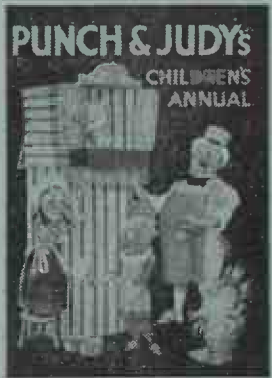
10 ins. x 7¼ ins.



A magnificent Annual dealing with life in the Circus. All old friends are here in pictures and stories.

2/6; By Post 2/10.

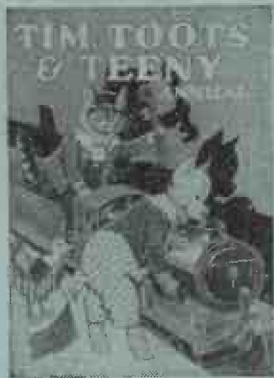
10 ins. x 7¼ ins



Everybody loves Punch and Judy, to say nothing of the famous dog Toby.

2/6; By Post 2/10.

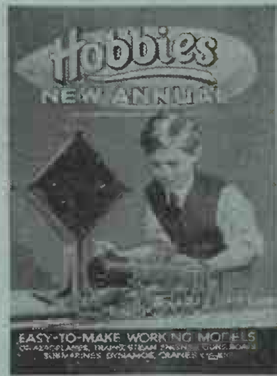
10 ins. x 7¼ ins.



All kiddies will enjoy this fine Monster Annual. Full of the comic antics of Tim, Toots and Teeny.

2/6; By Post 2/10.

10 ins. x 7¼ ins.



This Annual strikes an entirely new note. Contains simple and practical descriptions of working models of every type.

3/6; By Post 3/9.

(P.T.O)

c

This article on "Servicing PYE Receivers" is continued in Part 4. Ready October 7th. Order your copy to-day.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

CONTAINING

CHART FOR RADIO CABINETS

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

SHORT WAVE BROADCASTING

1/-

Part 4

IN ABOUT 24 WEEKLY PARTS

fixing tags at the base of the chassis released with a screw-driver. Two types of condenser bank are fitted to the "M.M." mains unit: either a 17 mfd. condenser bank or a 12 mfd. condenser bank with a separate 7 mfd. electrolytic condenser.

The 17 mfd. bank has 6 unit condensers as follows: C6, 2 mfd.; C9, 1 mfd.; C13, 4 mfd.; C14, 4 mfd.; C15, 3 mfd.; C16, 3 mfd.

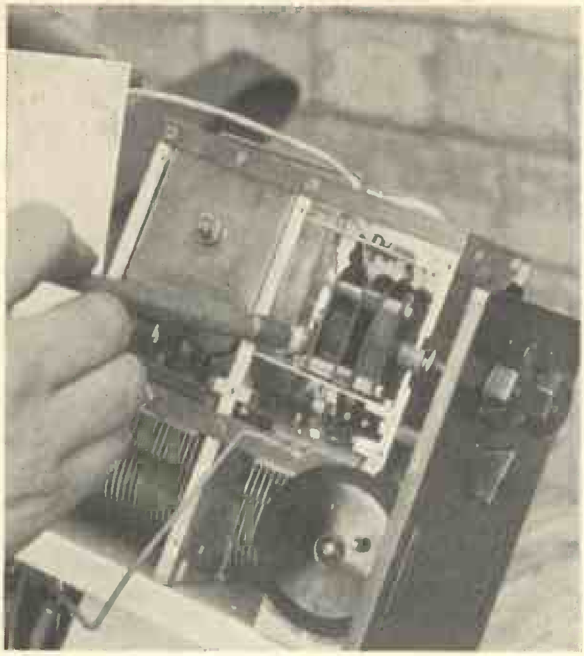


Fig. 14.—Cleaning the Volume Control.
This is done with a soft-haired brush, as shown.

The 12 mfd. bank has 5 unit condensers: C6, 2 mfd.; C9, 1 mfd.; C13, 3 mfd.; C15, 3 mfd.; C16, 3 mfd.; C14 being the separate electrolytic 7 mfd. condenser.

When a breakdown occurs in the 12 mfd. condenser or in units of the 17 mfd. condenser C6, C9, C15, C16 or both C13 and C14, it is necessary to fit a complete replacement condenser.

In the case of the 17 mfd. bank where only one of the 4 mfd. units (C13, C14) break down, a 7 mfd. electrolytic condenser should be fitted for C14, and the good 4 mfd. unit in the bank used for C13.

Checking the Chassis

If the fault has not been located in the mains unit, the components in the chassis should next be tested. To do this the chassis should be removed from the cabinet.

If an unsatisfactory reading is obtained in the anode circuit test (see page 155) the components associated in the particular circuit should be tested.

Check for Bad Joints, etc.

When testing these components, all connections should be examined for bad joints and the valve holders should be examined to make sure that proper connections are made with the valves. The resistances in the bias circuits should be carefully checked (R7, R8, R9, R11, R12). The intervalve transformer T1 and the condensers C10 and C18 should be tested.

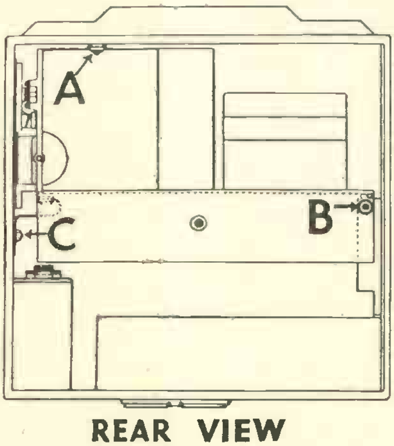


Fig. 15.—Showing Details for removing Chassis. (See also Fig. 10.)

Values of Resistances and Capacities (see Fig. 19)

Resistances:

- L.F. Transformer (T1) Primary 1,000 ohms, secondary 10,000 ohms.
- S.G. valve anode supply resistance (R1), 10,000 ohms.
- S.G. valve screened grid supply resistances (R2), 60,000 ohms. (R10), 40,000 ohms.
- Det. anode circuit choke (L3), 380 ohms.
- Det. anode supply resistances (R3), 10,000 ohms. (R4) 10,000 ohms.
- Pentode auxiliary grid supply resistance (R5), 2,000 ohms.
- Pentode tone compensating choke (L4), 20 ohms.
- Pentode bias resistance (R7), 250 ohms.

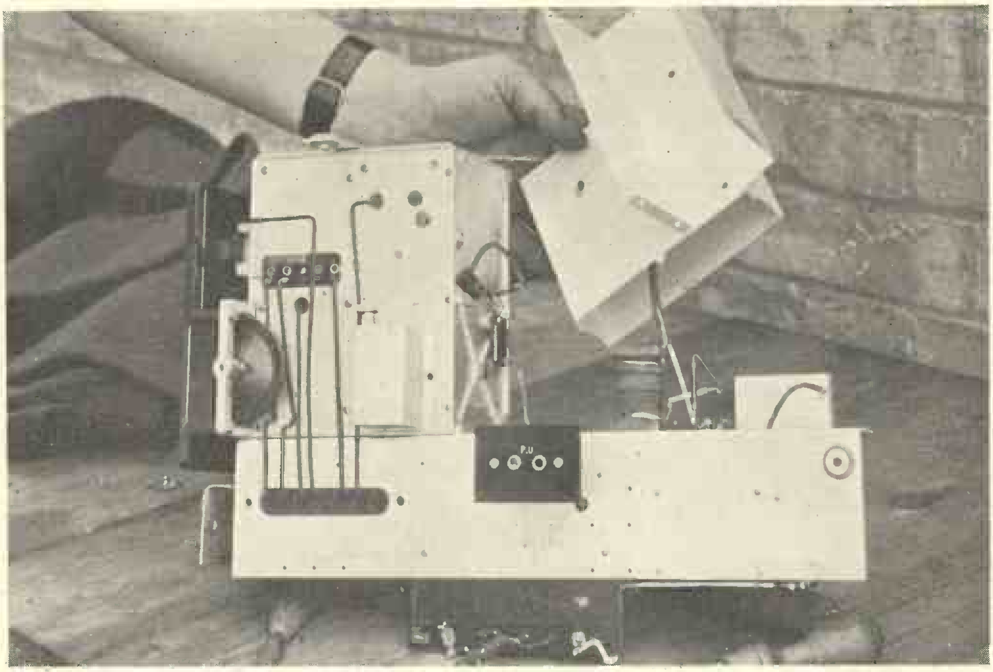


Fig. 16.—How to remove the Detector Screening Box of Pye "MM" Receiver.

Release the shielded cable from the cleats at the top of the screening box. Remove two screws holding the pentode valve screen to the valve platform. Release the cleats at the base of the screening box with a screwdriver; these will be seen on the underside of the valve platform. The screening box can now be gently lifted so that the components are accessible.

Fig. 17.—Checking Voltages while the Set is in Operation.

Fig. 18.—Checking Valve Outputs while Set is in Operation.

Output transformer primary (T2), 650 ohms.
Detector bias resistance (R8), 500 ohms.
Detector grid leak (R9), ·25 megohm.
S.G. valve bias resistance (R11), 40 ohms.
Volume control resistance (R12) max. 350 ohms.
Pilot light series resistance (R13), 6 ohms.
Regulating resistance (R14) 60,000 ohms. ± 25 per cent. (only fitted on recent models).

CAPACITIES :

S.G. valve screened grid by-pass condenser (C2), ·5 mfd.
S.G. valve anode by-pass condenser (C17), 1 mfd.

Testing Anode Circuits

A preliminary test of the anode circuits of the receiver can be made by checking the voltages at the valves in the table given.

The volume control should always be adjusted to a position midway between the minimum and maximum positions. The voltage readings should be taken with a high resistance voltmeter, while the set is in operation. If any reading is found to be low or shows no voltage at all,

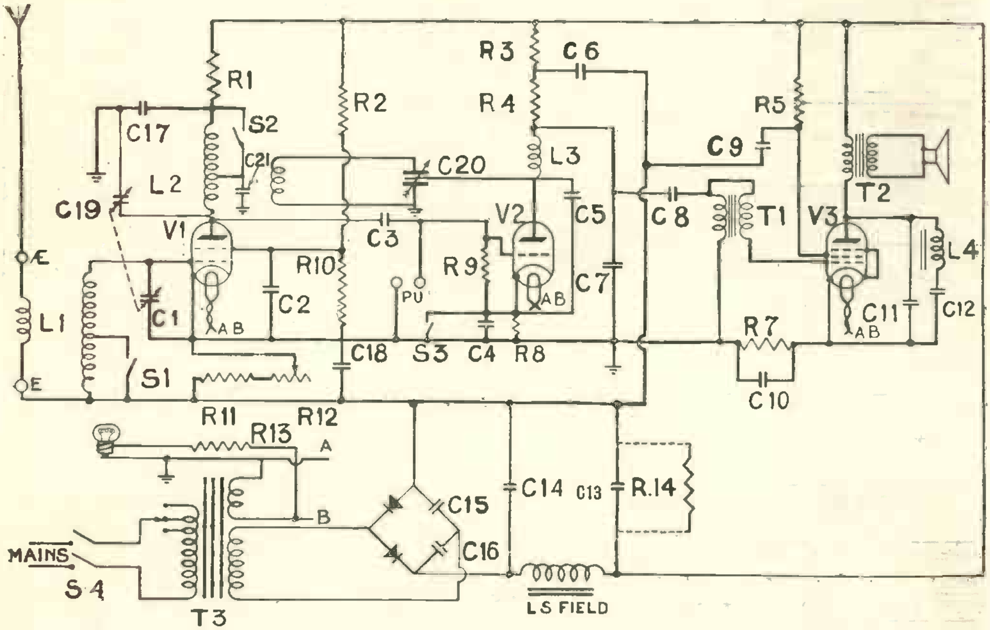


Fig. 19.—THEORETICAL DIAGRAM OF "MM" RECEIVER.

S.G. Det. coupling condenser (C3), ·0001 mfd.
Detector bias shunt condenser (C4), 1 mfd.
Detector anode (C5), ·001 mfd.
Detector anode by-pass condensers (C6), 2 mfd., (C7), ·002 mfd.
Det. L.F. coupling condenser (C8), ·5 mfd.
Pentode auxiliary grid by-pass condenser (C9), 1 mfd.
Pentode bias shunt condenser (C10), 10 mfd. electrolytic.
Pentode compensating circuit condensers (C11), ·002 mfd., (C12), ·005 mfd.
Mains smoothing condensers (C13) 4 mfd. or 7 mfd. electrolytic. (C14), 4 MF, 8 mfd., or 3 mfd.
Rectifier condensers (C15), 3 mfd., (C16), 3 mfd.
S.G. valve bias shunt condenser (C18), 10 mfd. electrolytic.

reference to the circuit diagram will show the components in that particular part of the circuit which can be suspected. The resistance of components should be tested with a resistance bridge.

AC/SG.	AC_2/HL.	AC/PEN.
Anode volts, 155–120 Screen grid volts, 55.	Anode volts, Radio 115, Gram. 156.	Anode volts, 185 Auxiliary grid volts, 187

Fig. 20.—TESTING EMISSION OF VALVES ON PYE "Q" RECEIVER.

Checking Components in the Mains Unit

The mains supply is transformed to 4 and 194 volts R.M.S. The former voltage is used for the valve heater circuit while the latter voltage is rectified by a Westinghouse voltage doubling metal rectifier giving 315 volts D.C. which is smoothed by the speaker field winding and the associated condensers. The output of the unit is 46 ma. 215 volts which is used for the high tension and grid bias supplies. Low voltage readings may be due to a broken down component in either the mains unit or the receiver chassis.

To check the components in the mains unit, the latter should be withdrawn from the cabinet as far as the wires will allow, after removing the four retaining screws. Test the voltages at the transformer secondaries with an A.C. voltmeter. These should read :

(1) Heater supply 4 volts.
(2) H.T. ,, 194 volts.

Test the D.C. working voltages across the condensers C13 and C14 as shown below.

The voltage across the loud speaker field should be 100 volts. The total output in ma. can be read by breaking the lead to C13 and inserting a milliammeter. A reading of approximately 46 ma. should be obtained. If readings exceeding plus or minus 10 per cent. are obtained, disconnect the mains supply and remove the mains unit from the cabinet. The wires should be unsoldered from the condenser and their insulation tested.

Condenser C13 ; Value, 3 mfd., 4 mfd., or 8 mfd. ; Working voltage, 215 volts (on load) taken

Fig. 21.—ADJUSTING THE LOUD SPEAKER.

This can be done with a coin as shown. Symptoms of a faulty loud speaker are : No results when set is switched on. Voltage low at anode of pentode or, in some cases, no reading at all.

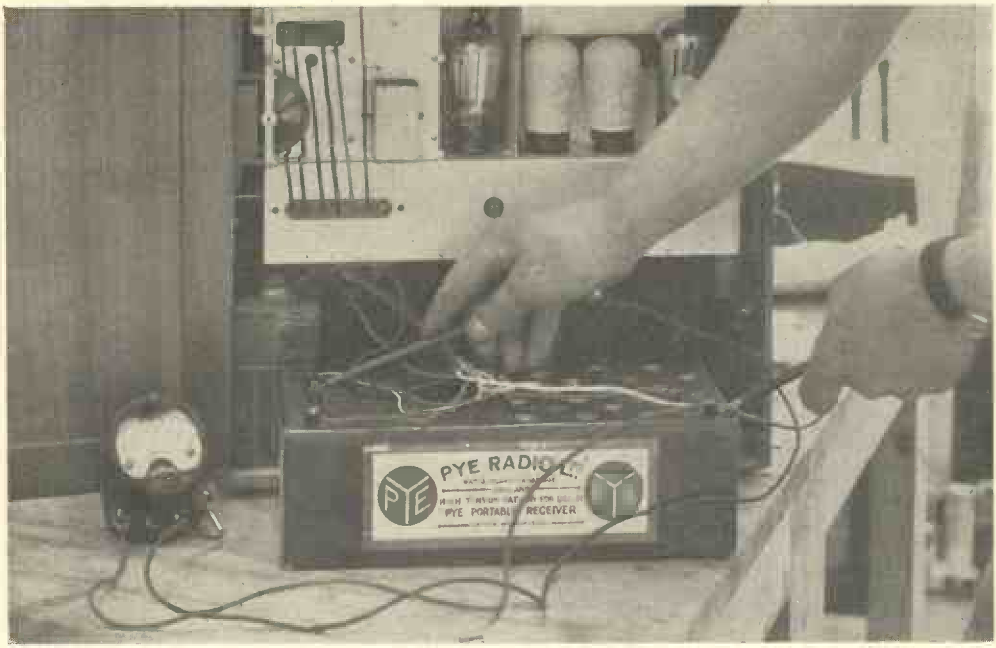


Fig. 22.—Testing the High Tension Battery on Load.

Special care should be taken to see that the HT3 lead is placed at correct voltage. This should be varied from time to time so that the total current taken by the HT4 lead remains at 6 milliamps. Average high tension consumption is 9 milliamps, and should never exceed 11 milliamps. Readings should be taken with volume control in half-way position.

between the chassis and the extreme right hand near contact of condenser bank. Condenser C14; Value, 4 mfd. in 17 mfd. bank or 7 mfd. electrolytic; Working voltage, 315 volts (on load) taken between the chassis and the near end of the metal rectifier. (Service Notes on the modified MM receiver will be given in a later section.)

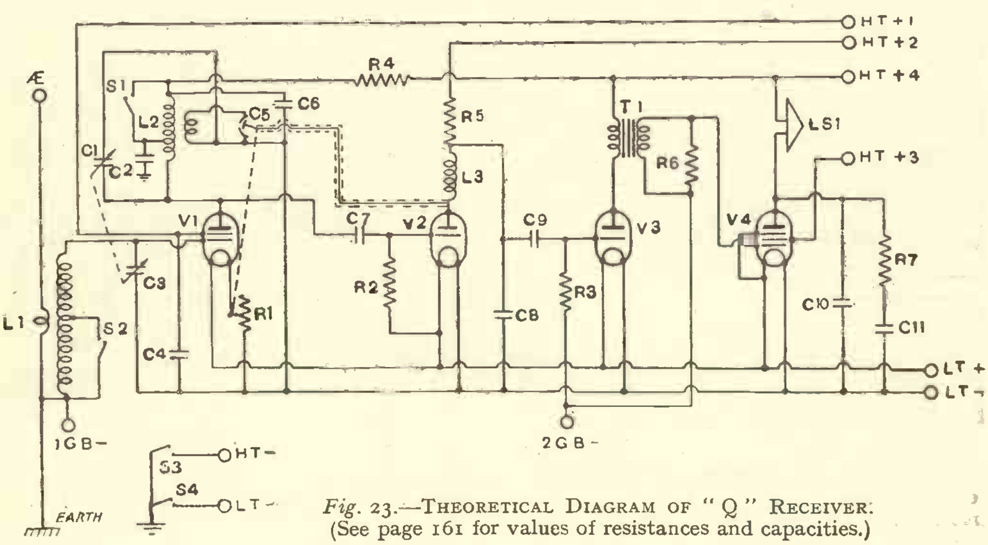


Fig. 23.—Theoretical Diagram of "Q" Receiver. (See page 161 for values of resistances and capacities.)

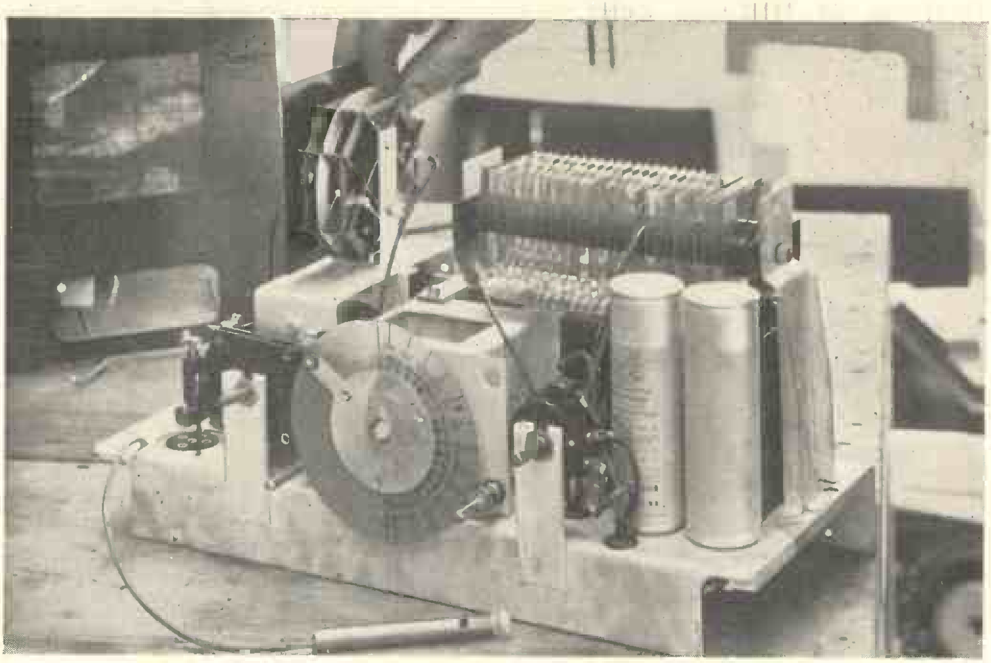


Fig. 24.—LONG WAVE BANDPASS SCREENING OF PYE " K " RECEIVER.

The " K " receiver incorporates a selective two-stage pre-selector circuit, and should be connected to a first-class outside aerial.

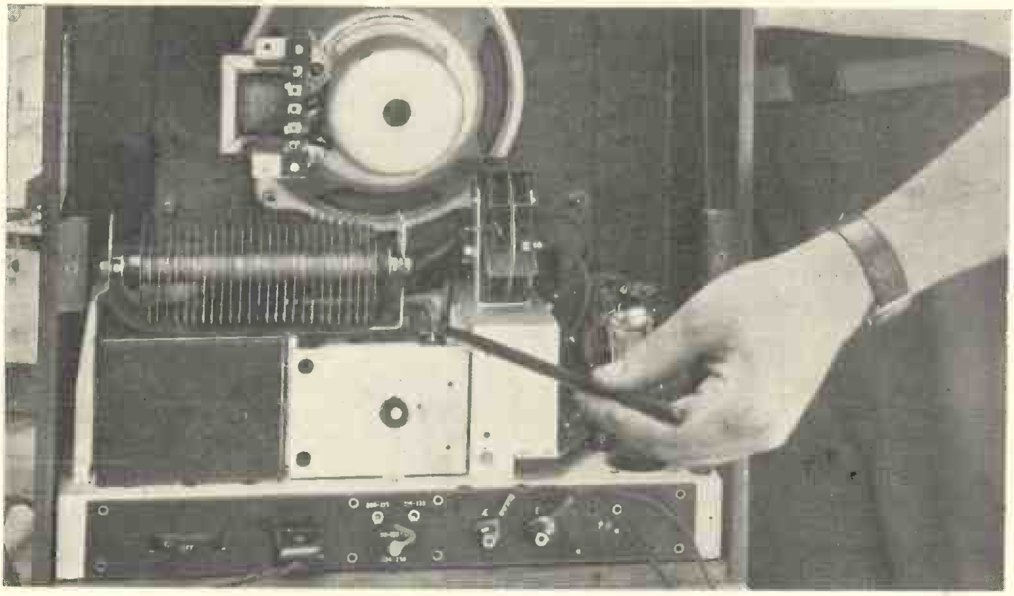


Fig. 25.—ADJUSTING THE TUNING CONDENSERS OF THE " K " RECEIVER.

The balancing of the two-ganged tuning circuits is effected by the adjustment of the small trimmer condenser fitted on the rear condenser unit while a weak transmitter of known wavelength is being received.

REMOVAL OF THE "Q" PORTABLE CHASSIS

The chassis can be easily removed from the cabinet, as follows :—

(1) Remove batteries and valves.

(2) Unsolder the following connections, after having affixed suitable indications to ensure correct replacements.

(*a*) The loud speaker connections from the contact strip near speaker magnet.

(*b*) Frame aerial connections from the contact strip at the bottom left-hand corner of the cabinet.

(3) Remove the following screws and nuts :—

(*a*) One screw in top interior of cabinet (A in Fig. 15).

(*b*) Screws on extreme right of metal baseplate (B in Fig. 15). These screws have rubber washers which must not be removed from the chassis.

(*c*) Two nuts on extreme left beneath tuning control panel (C in Fig. 15).

(4) The chassis can now be removed from cabinet. Withdraw the right-hand side first, so as not to damage the control panel.

Volume Control Faulty

SYMPTOMS.—When the volume control is adjusted a crackling noise develops, due to the slider contact becoming oxidised.

CURE.—A reinforced nickel slider has been designed, which completely overcomes this trouble. It should be fitted as follows :—

(1) Remove chassis from cabinet (see instructions already given).

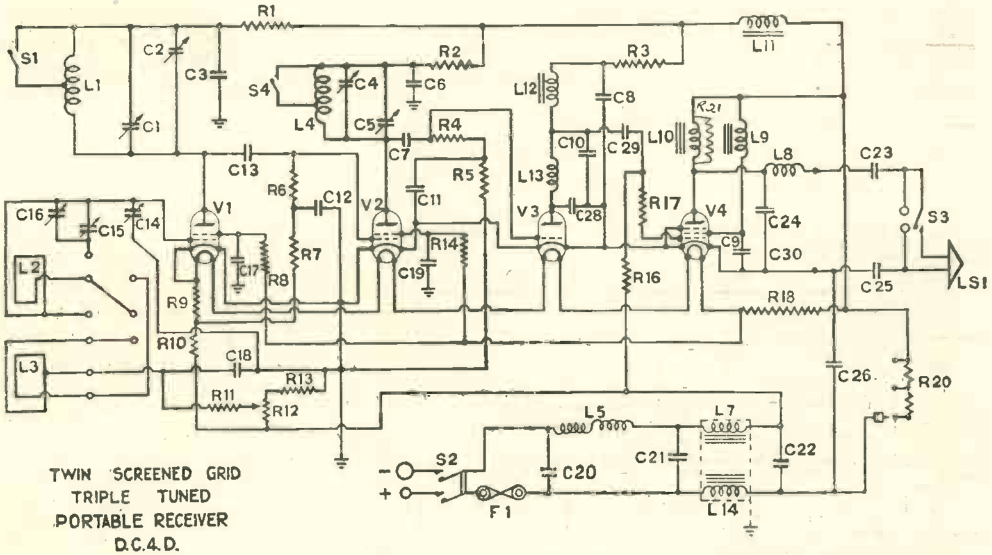


Fig. 26.—THEORETICAL DIAGRAM OF PYE D.C.4D. RECEIVER (SERIES F.).

Values of resistances and capacities are as follows :—

RESISTANCES.—R1, 5,000 ohms ; R2, 5,000 ohms ; R3, 2,000 ohms ; R4, ·1 megohm ; R5, ·1 megohm ; R6, ·25 megohm ; R7, ·1 megohm ; R8, 2,000 ohms ; R9, 5 ohms ; R10, 27 ohms ; R11, 10,000 ohms ; R12, 25,000 ohms variable ; R13, 2,000 ohms ; R14, 2,000 ohms ; R16, ·25 megohm ; R17, ·1 megohm ; R18, 480 ohms ; R20, 2 units of 75 ohms ; R21, 10,000 ohms ; L2 and L3 : long wave 30 ohms, short wave 2 ohms ; L1, long wave 40 ohms, short wave 3·7 ohms ; L4, long wave 40 ohms, short wave 3·7 ohms ; L5, 2·5 ohms ; L7, 15 ohms ; L8, 380 ohms ; L9, 450 ohms ; L10, 450 ohms ; L11, 600 ohms ; L12, 2,400 ohms ; L13, 380 ohms ; L14, 15 ohms ; speaker, 3,000 ohms.

CAPACITIES.—C1, C4, C15, ganged variable condensers with their associated trimmers, C2, C5 and C16 ; C3, ·5 mfd. ; C6, ·5 mfd. ; C7, ·0001 mfd. ; C8, 1 mfd. ; C9, 2 mfd. ; C10, ·0003 mfd ; C11, 1 mfd. ; C12, 1 mfd. ; C13, ·0001 mfd. ; C17, ·25 mfd. ; C18, ·5 mfd. ; C19, ·25 mfd. ; C20, 1 mfd. ; C21, 4 mfd. ; C22, 4 mfd. ; C23, 2 mfd. ; C24, ·002 mfd. ; C25, 1 mfd. plus 1 mfd. ; C26, 2 mfd. ; C28, ·001 mfd. ; C29, ·25 mfd.

(2) Place chassis on bench with control panel to your right and the base towards you. Important: In no circumstances may balancing adjustments be touched. These are adjusted with special apparatus at the works and do not need readjustment unless coil is replaced.

(3) Remove (*a*) the 8 cheese-head screws which hold the screen to chassis, (*b*) one screw situated on valve platform between S.G. and detector valve holders, and (*c*) the screen, by releasing the clip which holds flex.

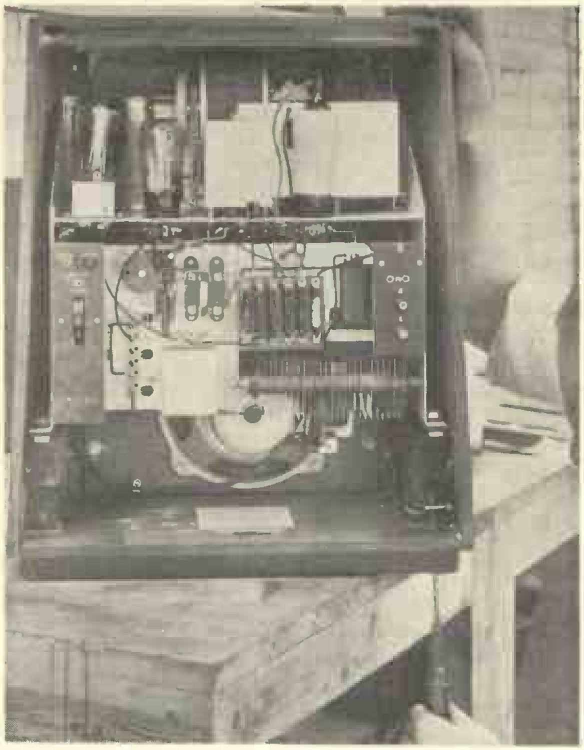


Fig. 27.—Removing the Chassis Bolts of the "G" Receiver.

(4) Turn the volume control, which will be seen at the top right-hand corner of the chassis, to its maximum reading.

The sliding contact of the volume control will be seen fastened to the driving spindle by a fixing screw.

(5) Release fixing screw. The slider arm can now be removed by rotating in an anti-clockwise direction.

(6) Wipe the resistance clean and apply a small amount of vaseline along the contact surfaces.

(7) When refitting the reinforced slider make sure that the fixing screw engages slot in driving spindle.

(8) Replace screen and chassis.

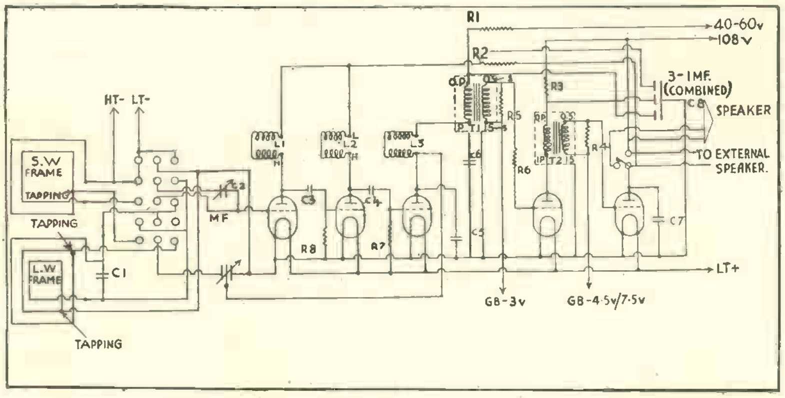


Fig. 28.—Theoretical Diagram of Pye 25c Portable Receiver.

Values of resistances and capacities are as follows :—

Resistances.—R1, 15,000 ohms ; R2, 15,000 ohms ; R3, 15,000 ohms ; R4, ·5 megohm ; R5, ·5 megohm ; R6, ·1 megohm ; R7, 3 megohms ; R8, 2 megohms ; short-wave frame aerial in front of cabinet, 1·5 ohms ; long-wave frame aerial in door of cabinet, 21 ohms ; L1 choke, 135 ohms ; L2 choke, 48 ohms ; L3 choke, 270 ohms ; primaries of transformers T1 and T2, 1,000 ohms ; secondaries of transformers T1 and T2, 10,000 ohms ; speaker, 2,000 ohms.

Capacities.—C1, ·0001 mfd. ; C2 (variable), ·0005 mfd. ; C3, ·0002 mfd. ; C4, ·0001 mfd. ; C5, ·0008 mfd. ; C6, ·0003 mfd. ; C7, ·002 mfd. ; C8 (units), 3·1 mfd.

Switch Control Bad Contact

SYMPTOMS.—A crackling noise, with weak or intermittent results which vary with adjustments of switch.

CURE.—Clean and adjust contacts.

The procedure is as follows :—

(1) Remove chassis from cabinet. The unscreened top of chassis provides an easy access to the switch.

(2) Brush all dust from the contacts.

(3) Apply a small amount of vaseline to wiper arm and contact springs.

(4) Carefully bend switch contacts so that wiper arm makes a firm connection with the contacts. Do not bend contact springs so that wiper arm fouls the end of the contact springs.

Fig. 29.—HOW TO REMOVE THE KNOBS OF THE "K" AND "G" MODELS.

This is done with two loops of string and enables the knobs to be removed without damaging the front.

Values of Resistances and Capacities

RESISTANCES (see Fig. 23) :

Long wave frame aerial, 28 ohms. Short wave frame aerial, 2 ohms. H.F. Choke det. anode circuit (L3), 380 ohms. L.F. Transformer (T1), Primary 1,000 ohms, Secondary 10,000 ohms. Loud speaker, 2,500 ohms. Detector

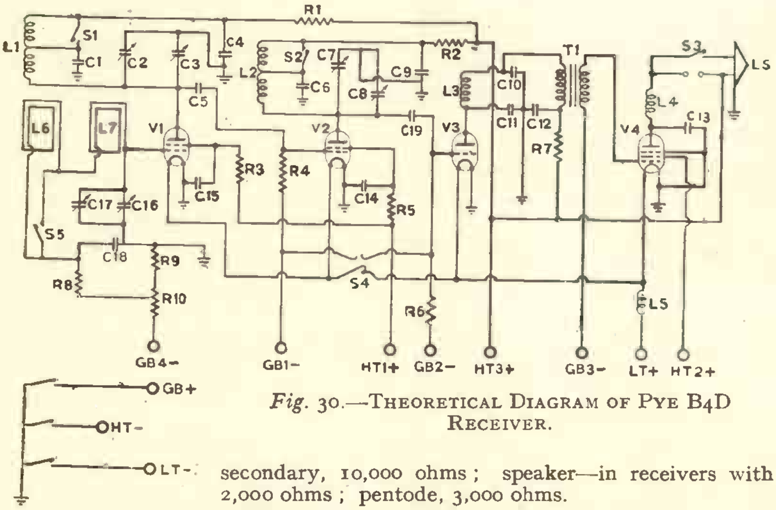


Fig. 30.—THEORETICAL DIAGRAM OF PYE B4D RECEIVER.

Value of resistances and capacities are as follows :—

RESISTANCES. — R1, 2,000 ohms ; R2 2,000 ohms ; R3, 2,000 ohms ; R4, 2 megohms ; R5, 2,000 ohms ; R6, 1 megohm ; R7, 2,000 ohms ; R8, 1,000 ohms ; R9, 2,000 ohms ; R10 variable, 25,000 ohms potentiometer ; L1 (long), 40 ohms, (short) 3·7 ohms ; L2 (long), 40 ohms, (short) 3·7 ohms ; L3, 380 ohms ; L4, 380 ohms ; L6, L7, frame aerials, (long), 28 ohms, (short), 2 ohms ; T1 primary, 1,000 ohms, secondary, 10,000 ohms ; speaker—in receivers with a triode output value, 2,000 ohms ; pentode, 3,000 ohms.

CAPACITIES.—C1, 18 m. mfd. ; C2, C7, C17 are ganged variable condensers with their associated trimmers ; C3, C8, C16, C4, ·25 mfd. ; C5, ·0002 mfd. ; C6, 18 m. mfd. ; C9, ·25 mfd. ; C10, ·0003 mfd. ; C11, ·0003 mfd. ; C12, 1 mfd. ; C12, ·002 mfd. ; C14, ·25 mfd. ; C15, ·25 mfd. ; C18, ·25 mfd.

grid leak (R2), ·5 megohm. 1st L.F. valve grid leak (R3) ·25 megohm. S.G. anode supply resistance (R4), 2,000 ohms. Detector anode supply resistance (R5), 25,000 ohms. Resistance shunted across secondary of L.F. transformer (R6), ·25 megohm. Tone compensating resistance (R7), 25,000 ohms.

Capacities :

S.G. valve screened grid by-pass condenser (C4), ·25 mfd. S.G. valve anode by-pass condenser (C6), 1 mfd. S.G. det. coupling condenser (C7), ·0002 mfd. Det. anode by-pass condenser (C8), ·002 mfd. Det. 1st L.F. coupling condenser (C9), ·25 mfd. Pentode output circuit compensating condensers (C10), ·002 mfd. (C11), ·005 mfd. C1 and C3 and C5 are variable.

REMOVAL OF 25C CHASSIS FROM CABINET

When it is necessary to remove the chassis from the cabinet to examine the components, the following procedure should be followed :—

(1) Remove bakelite dust cover after taking out the seven holding screws.

(2) Attach suitable indicators and then unsolder the loud speaker leads from contact strip on chassis baseboard. Unsolder leads to the short wave frame aerial contact strip in bottom left-hand corner of cabinet. Unsolder leads to the long-wave aerial in cabinet door.

(3) Remove the following screws holding chassis to cabinet :—

(*a*) Two screws—one in top left-hand corner and one in top right-hand corner of cabinet.

(*b*) Four screws—two on either side below the chassis baseboard.

(4) Release the two screws below the control panel and remove strip of wood.

REMOVAL OF THE CHASSIS. TYPES AC4D, BC4D, and B4D

The procedure is as follows :—

(1) Unsolder two connections from speaker at jack switch.

(2) Fix suitable indications to aerial leads and unsolder at contact strip where leads join the frame aerial.

(3) Unsolder wire "earthing" speaker to chassis.

(4) Remove wave-change switch knob.

(5) Remove the two screws and brackets holding chassis at top of cabinet.

(6) In case of B4D model, loosen clamp holding H.T. and G.B. wires to chassis platform and remove chassis. AC4D models, remove three screws holding chassis to base of cabinet, when chassis can be removed.

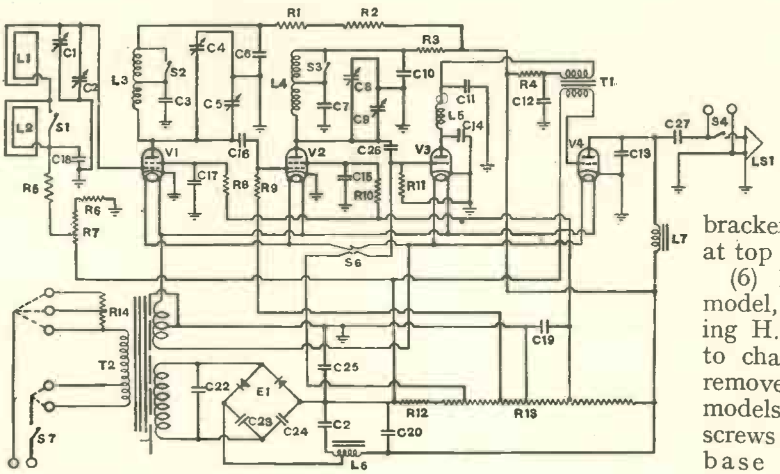


Fig. 31.—Theoretical Diagram of Pye AC4D Receiver.

Values of resistances and capacities are as follows :—

Resistances.—R1, 6,000 ohns ; R2, 10,000 ohms ; R3, 6,000 ohms ; R4, 10,000 ohms ; R5, 10,000 ohms ; R6, 2,000 ohms ; R7, 25,000 ohms variable ; R8, 2,000 ohms ; R9, ·25 megohm ; R10, 2,000 ohms ; R11, ·25 megohm ; R12, 165 ohms ; R12A, 325 ohms ; R12B, 50 ohms ; R13, 50 ohms ; R13A, 17,000 ohms ; R13B, 24,000 ohms ; R14, two units of 72 ohms.

Capacities.—C1, C4, C8 ganged variable condensers with C2, C5, C9, their associated trimmers ; C3 and C7, 18 m. mfd. ; C6, ·5 mfd. ; C10, ·5 mfd. ; C11, ·0003 mfd. ; C12, 1 mfd. ; C13, ·002 mfd. ; C14, ·001 mfd. ; C15, ·25 mfd. ; C16, ·0001 mfd. ; C17, ·25 mfd. ; C18, ·25 mfd. ; C19, 2 mfd. ; C20, 4 mfd. ; C21, 2 mfd. ; C22, ·01 mfd. ; C23, 4 mfd. ; C24, 4 mfd. ; C25, 80 mfd. electrolytic ; L1 and L2 frame aerials : long wave 30 ohms, short wave 2 ohms ; L3 : long wave 40 ohms, short wave 3·7 ohms ; L4 : long wave 40 ohms, short wave 3·7 ohms ; L5 : 380 ohms ; L6 : 600 ohms ; L7 : 420 ohms ; T1 : primary 1,000 ohms, secondary 10,000 ohms ; loud speaker : 2,000 ohms.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION IV—THE ELECTRICAL CIRCUIT

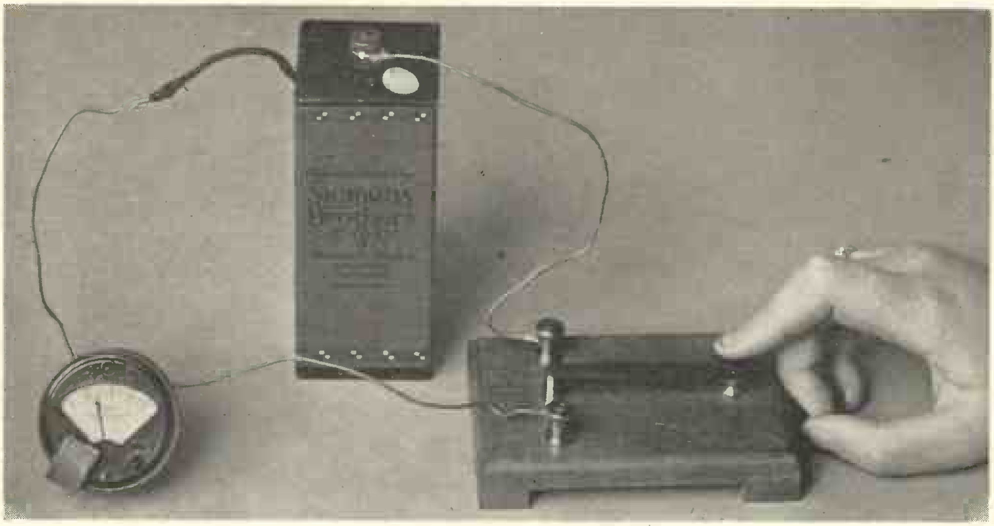


Fig. 1.—SERIES AND PARALLEL CONNECTION OF CELLS.

Here we see a single cell giving a reading of about $1\frac{1}{3}$ volts. The series and parallel connections of three such cells are shown in Figs. 5 and 6.

NOW that we have made the acquaintance of our little mobile friends, electrons, and their still smaller, but much heavier and therefore far more passive "affinities," protons, we are in a position to exploit the attractive force existing between the two, make electrons go the merry round of the electrical circuit and do a bit of useful work.

For this purpose we have to provide an uninterrupted chain of conductors surrounded by some insulating material, so that the electrons are confined to a "straight and narrow path," and cannot escape to earth.

ELECTROMOTIVE FORCE

Let us consider the simplest form of an electrical circuit consisting of a single piece of insulated copper wire. Such a circuit is shown in Fig. 2. We now know that the copper wire consists of innumerable atoms which are never at rest and are moving to and fro at tiny distances from each other, and that in addition to that each atom has a nucleus of protons and *cementing electrons* with a number of *planetary electrons* * rotating around the nucleus. Each of the planetary electrons has an orbit of its own, and can, under compulsion, leave this orbit and pass on to another atom. For this to happen the other atom must be deficient of an electron, or, in other words, must have a proton unbalanced. The unbalanced proton will do the attracting.

Now, suppose that we rob the point B of our circuit of some of the electrons in its atoms and transfer the proceeds of this robbery to the atoms at the point A. This will result in a *difference in the number of electrons per atom* at the two points, and while each atom at point A will have an

* See page 111.

excess of electrons, each atom at the point B will be left with a number of protons unbalanced. The unbalanced protons at B will try to get their electrons back. They cannot do this at the expense of the atoms in the molecules of the surrounding air, as the latter, if dry, is an insulator, *i.e.*, its planetary electrons are too strongly attached to their nuclei, and, similarly, they cannot borrow any electrons from the atoms of the insulating substance surrounding the copper wire for the same reason.

Borrowing from the Copper Atoms

Thus, if there is to be any borrowing done it has to be done at the expense of the copper atoms. And this is precisely what will happen. The unbalanced protons in the atoms of copper at B will help themselves to all the close-lying electrons they can get from the copper atoms next to them. The latter, having been robbed of some of their electrons, will have protons unbalanced, and these protons will compensate themselves from the next layer of atoms, and so the exchange of electrons will go on from point to point till the atoms next to the point A will draw on the surplus of electrons that is to be found there. The net result is a drift of electrons from A to B.

Fig. 2.—THE SIMPLEST FORM OF ELECTRICAL CIRCUIT.

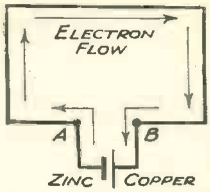


Fig. 3.—THE CIRCUIT WITH A CELL ADDED.

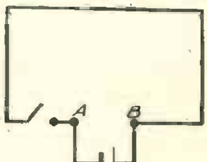


Fig. 4.—THE CIRCUIT BROKEN BY MEANS OF A SWITCH.

At the end of this drift the surplus of electrons at A has disappeared, and if we want to repeat the process we shall have once more to rob some electrons at B and transfer them to A.

What the Electromotive Force is

The force which moves electrons from atom to atom from one end of the circuit to the other end is the attractive force due to exposed or unbalanced protons at one end. It is this force that we call the electromotive force, as it moves electrons from one end to another.

The Primary Cell

It is clear that if this migration of electrons from atom to atom is to be of any use for practical purposes, and is to last for any considerable time, we have to invent a means of automatic robbery of electrons at one end of the circuit, and an automatic transfer of the proceeds to the other end.

This can be done by several means, which will all be considered in their turn; but for the time being let us consider the so-called *primary cell*, which is an excellent robber of electrons.

What the Cell Consists of

The primary cell consists of two *different* metals, such as copper and zinc, immersed into suitable acids. When the two metals are joined to the ends of the circuit the acid molecules and atoms within these molecules will act upon copper, robbing its atoms of some of their electrons, drift across to the zinc and deposit the proceeds of the robbery upon it.

What Happens Inside the Cell

This process will go on indefinitely while the chemical materials last, and the zinc plate of the cell will carry permanently an excess of electrons, while the copper plate of the cell will have a chronic deficit of electrons, and therefore a number of protons, exposed, *i.e.*, unbalanced. This being the case, it is clear that the copper plate of the cell, being deficient of electrons will borrow them from the copper conductor, and the copper conductor atoms will compensate themselves from the atoms of the zinc plate of the cell. For this reason there will be all the time a drift of electrons from the zinc plate to the copper plate through the wire, outside the cell, as well as a movement of electrons from the copper to the zinc *inside* the cell.

As you see, the copper plate of the cell does not lose its electrons permanently,

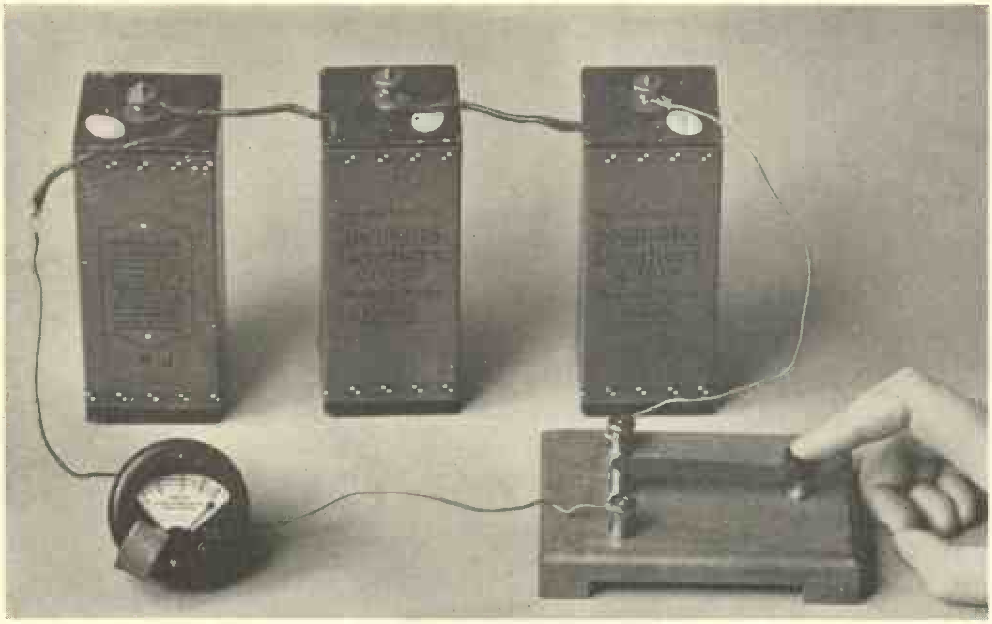


Fig. 5.—THREE CELLS CONNECTED IN SERIES.

We saw in Fig. 1 that the voltage of a single cell was about $1\frac{1}{3}$ volts. Here we see that the voltage of three such cells connected in series amounts to about 4 volts, *i.e.*, the sum of the voltages of the individual cells. *This battery would deliver the same current as a single cell.*

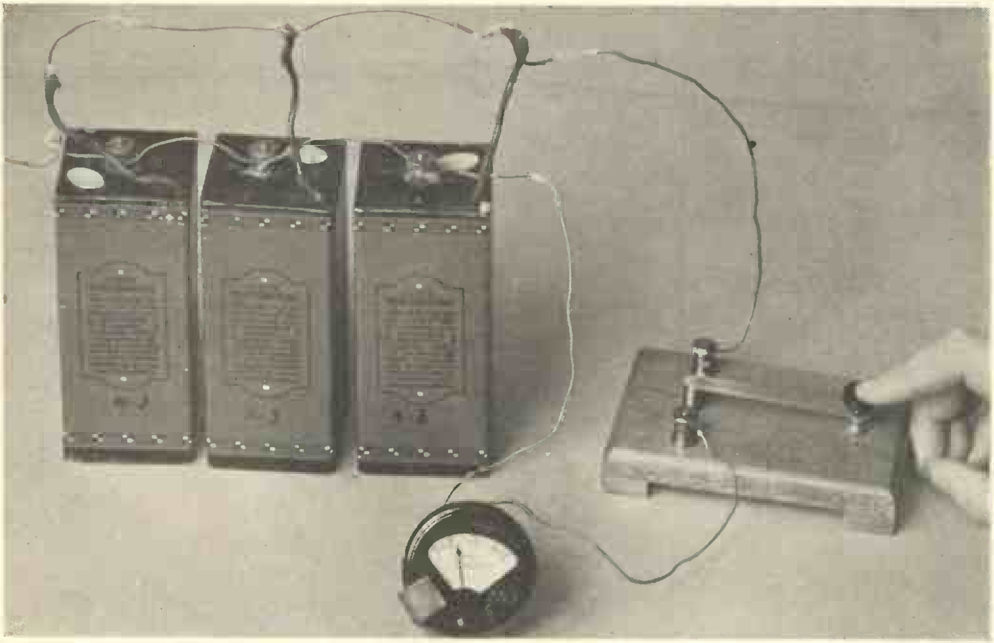


Fig. 6.—THREE CELLS CONNECTED IN PARALLEL.

Here it will be seen that the voltage is just over one and a third, which is the same as that of a single cell (see Fig. 1). *This battery will deliver three times the current obtainable from a single cell.*

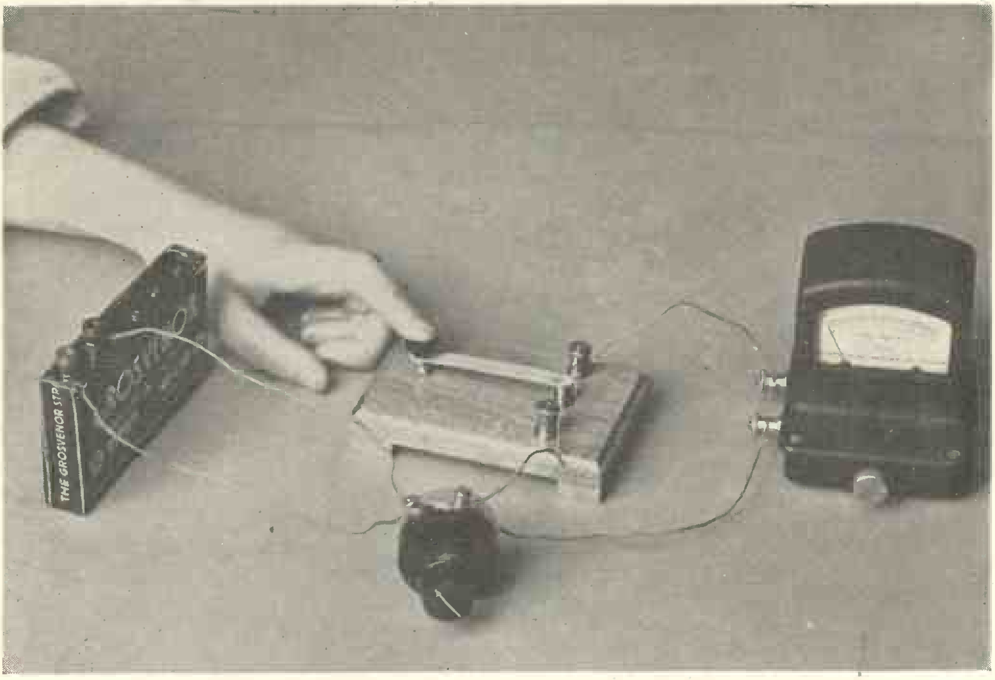


Fig. 7.—The Increasing Increment or Logarithmic Potentiometer.
Here the potentiometer is in the off position, and it will be seen that there is no reading on the meter.

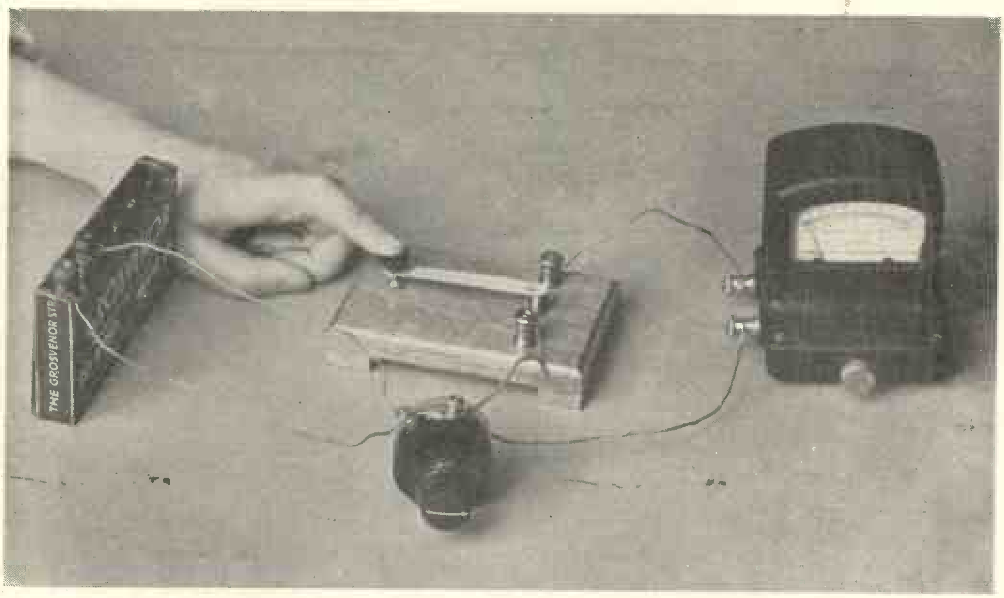
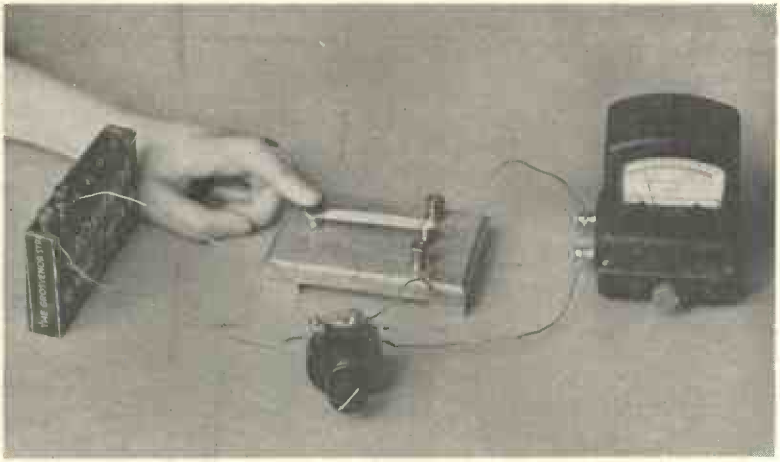


Fig. 8.—The Increasing Increment or Logarithmic Potentiometer.
In this photograph the potentiometer has been given about a quarter of a turn, and it will be seen that this picks off a small voltage across the tapping key and instrument circuit.

Fig. 9.—(Right).—THE INCREASING INCREMENT OR LOGARITHMIC POTENTIOMETER.

The potentiometer has now been given about three-quarters of a turn, and the meter shows an increased voltage being picked off.



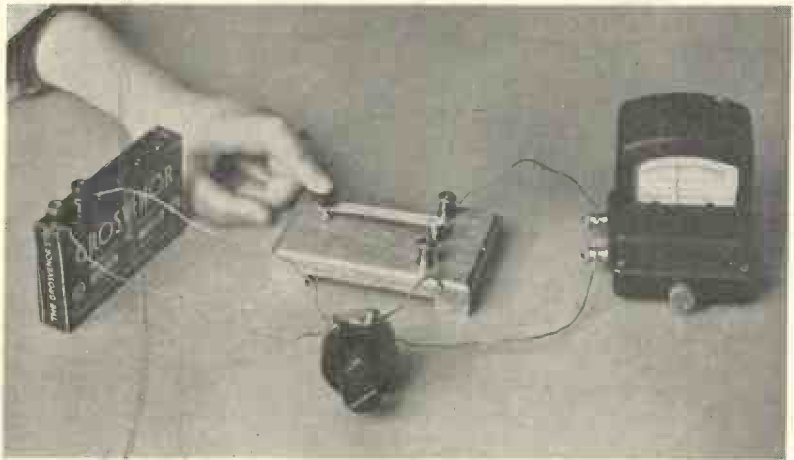
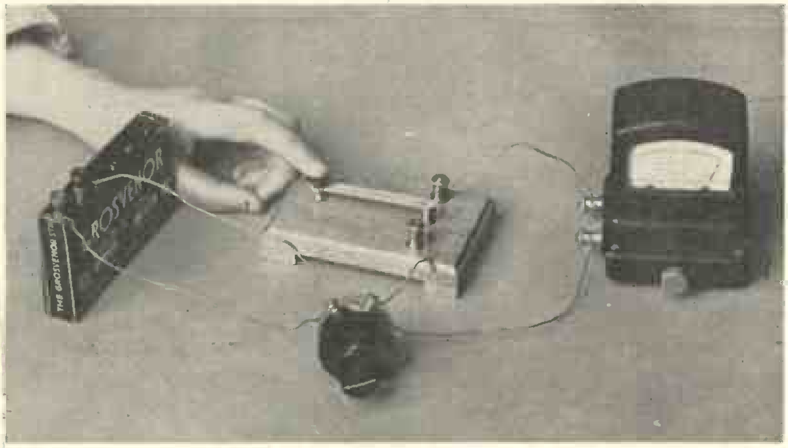


Fig. 10.—(Left).—THE INCREASING INCREMENT OR LOGARITHMIC POTENTIOMETER.

Now the potentiometer is nearly full on, and the needle of the meter is almost half-way across the scale. Note that after this point a very slight increase of the potentiometer control causes a big increase in the voltage picked off.

Fig. 11.—(Right). THE INCREASING INCREMENT OR LOGARITHMIC POTENTIOMETER.



Here we see a slight increase in the potentiometer control has caused the needle to move to the extreme right of the scale. It should be noticed that the use of a potentiometer of this type gives an extremely smooth graduation in the picked off voltage when the potentiometer control is turned. This is due to the fact that this type of potentiometer, the Lewcos, consists of an enormous number of turns of fine wire wound on a circular former, contact being made by means of a swash-plate.

but merely lends them to the acid for transfer to the zinc, and then gets them back again *viâ* the copper wire constituting our outside circuit.

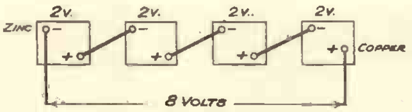


Fig. 12.—Diagrammatic Representation of Four 2-volt Cells in Series. The Total Voltage is 8.

Constant Flow of Electrons

The complete circuit consists now of copper wire and the cell (Fig. 3). The exchange of electrons between the atoms of the materials composing the circuit is so rapid that in practice we get a constant flow of electrons round the circuit, a flow that can be utilised to do useful work.

Stopping the Migration of Electrons

Since acids are used inside the cell, and chemical processes are taking place, in time the materials composing the cell get consumed and the action becomes less efficient as time goes on, and will cease altogether unless the materials in question are replaced. For this reason, economy in the use of the cell is necessary, and a means has to be provided to stop the migration of electrons when the circuit is not in use. This is done by " breaking " temporarily the continuity of the circuit by means of a switch, as shown in Fig. 4. When the switch is open the circuit is broken and the flow of electrons ceases. On closing the switch a continuous path is once more provided, and the electrons are free to migrate. This is the most primitive means of control of electron flow.

PRESSURE AND TENSION

Since a cell is capable of establishing a difference in the number of electrons *per atom* at two ends of a circuit, and thus bring into existence a force acting on the planetary electrons of the atoms of a conductor, so that they migrate from atom to atom, it produces a measurable effect.

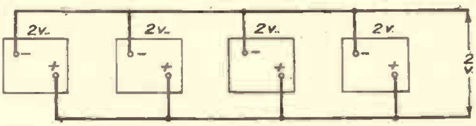


Fig. 13.—Diagrammatic Representation of Four 2-volt Cells in Parallel. The Combined Voltage remains 2.

It can be said that a cell establishes a *pressure* upon the electrons of the circuit, or that it produces a *tension* between the unbalanced protons at one end and the surplus electrons at the other end.

The words *electromotive force, pressure* and *tension* used in connection with an electrical circuit mean the same thing, viz., the force of attraction between unbalanced protons and unbalanced or surplus electrons.

The Unit Volt

This force is measured in units called *volts* (after an Italian scientist, Volta). A Weston cadmium cell, working at a temperature of 20° C., is taken as the standard of electromotive force, and the unit volt is defined as being $\frac{1}{1{\cdot}01865}$ of the electromotive force of that cell. As it happens, there is no cell giving exactly 1 volt, and the Weston cadmium cell is the nearest to it, being just a trifle over 1 volt.

The electromotive force of zinc-copper primary cell is higher than that of the standard cadmium cell, and is approximately 1·5 volts, while the accumulator cell (lead) supplies 2 volts.

Voltage Depends on Materials Used

The electromotive force of a cell, or, as it is commonly said, the voltage of a cell, does not depend on the size of the cell, but on the nature of the materials used. Since each material has a different number of electrons and protons in the atom, some materials will produce a greater difference in the number of electrons per atom than others.

Series Connection

If we wish to increase the voltage acting between two points of a circuit (we usually say *the voltage across a circuit*) we can do so by using a number of cells joined in a certain way.

For this purpose we connect the zinc terminal of one cell to the copper terminal of the next cell, and the zinc terminal of the second cell to the copper terminal of the third cell, and so on, as shown in Fig. 12. As you see, such a combination has one zinc terminal free and one copper terminal free. This method of connection is called the *series connection*.

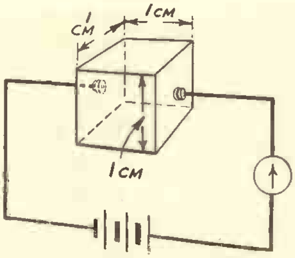


Fig. 14.—DIAGRAM SHOWING HOW SPECIFIC RESISTANCE IS MEASURED.

When cells are joined in series the resultant electromotive force (E.M.F. for short) is the sum of the E.M.F.'s of individual cells. Thus, if we were to join five cells in series, each cell having an E.M.F. of 2 volts, we should have a resultant E.M.F. of 10 volts. Fifty cells of 2 volts each, so joined, would give an E.M.F. of 100 volts.

Since the zinc terminal of a cell is rich in electrons, and the electron is a particle of "negative" electricity, we shall call the zinc terminal the negative terminal, and the copper terminal the positive terminal. This will apply to every kind of cell, the terminal rich in electrons being referred to as the negative terminal, and the other terminal as the positive terminal.

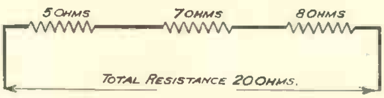


Fig. 15.—SERIES RESISTANCES.
The total resistance is the sum of the individual resistances.

Parallel Connection

There is another method of connecting cells, called the *parallel method*. In this case all the negative terminals are joined together and all the positive terminals are joined together, as shown in Fig. 13. In this case the resultant E.M.F. of the combination is the E.M.F. of a single cell. Apparently nothing is gained in this case, as the voltage is not increased. The advantage of such a combination is that each cell supplies its share of electrons, so that the more cells are joined in parallel the fewer electrons are required from the negative terminal of each cell. This means the slowing down of chemical processes inside each cell, and therefore a longer "life" of each cell.

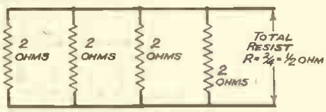


Fig. 16.—PARALLEL RESISTANCES.
The final resistance is less than any single resistance.

To sum up: we connect cells in series when we want to obtain a higher voltage, and we connect cells in parallel when we want the cells to last longer.

RESISTANCE

If you follow in your mind's eye the migration of electrons from atom to atom inside a copper conductor, you will realise that while an unbalanced proton is attracting an electron the planetary electrons around the nucleus in which the unbalanced proton is to be found are repelling the electron in question.

It is clear, therefore, that the planetary electrons in an atom resent and try to resist the invasion of their atom by a strange electron. The electrons migrating from atom to atom experience for this reason a good deal of opposition or *resistance* from the planetary electrons, a resistance which is bound to reduce their numbers. When such a resistance is great, few electrons can get through from one atom to another.

Every material has its own number of protons and electrons in the atom. This means that every material has its own number of planetary electrons. Thus for instance, copper has 29 planetary electrons, silver 47, tin 50, platinum 78, gold 79, mercury 80, lead 82 and bismuth 83. Thus, it is clear that every material will offer a resistance of its own to the passage of migrating electrons. Mark you, the number of planetary electrons is not the only thing that determines the particular resistance or, as we call it, the *specific*

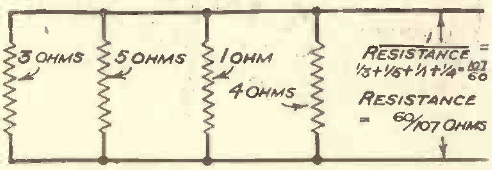


Fig. 17.—PARALLEL RESISTANCES.
Another example showing how the final resistance is less than any single resistance.

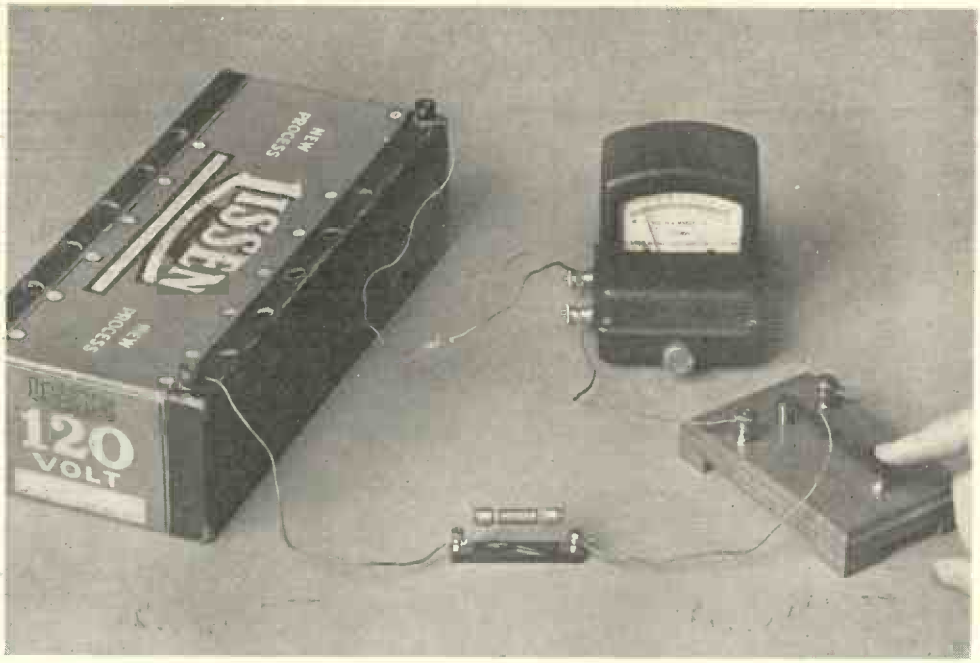


Fig. 18.—RESISTANCES IN SERIES AND IN PARALLEL.

Here a 2-meg. grid leak is shown connected in series with a battery and meter. Note that the reading is about 15 degrees.

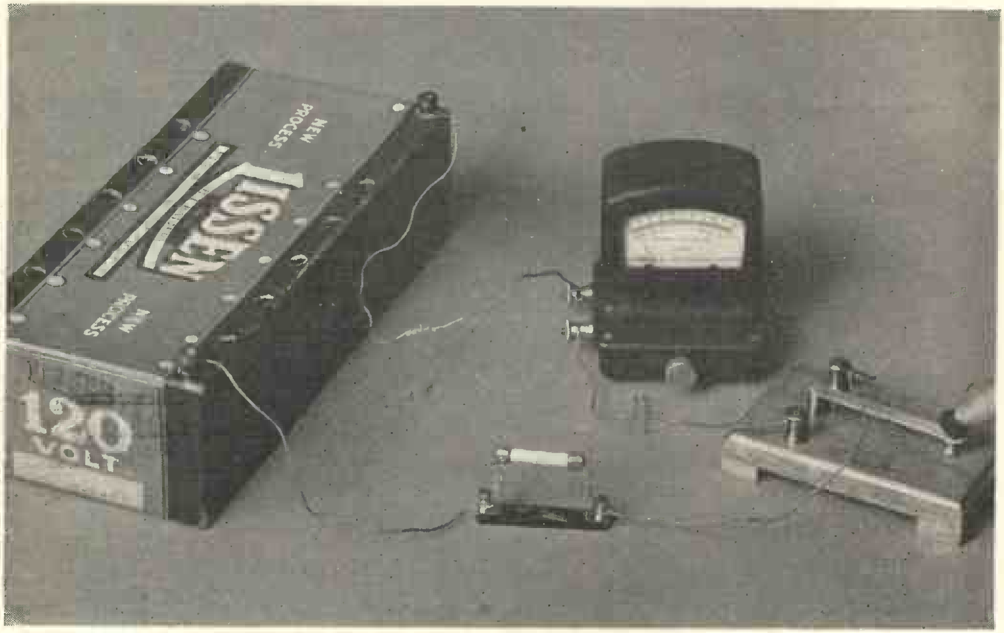


Fig. 19.—RESISTANCES IN SERIES AND IN PARALLEL.

This shows a 5-meg. grid leak. Note that the reading is about 6 degrees.

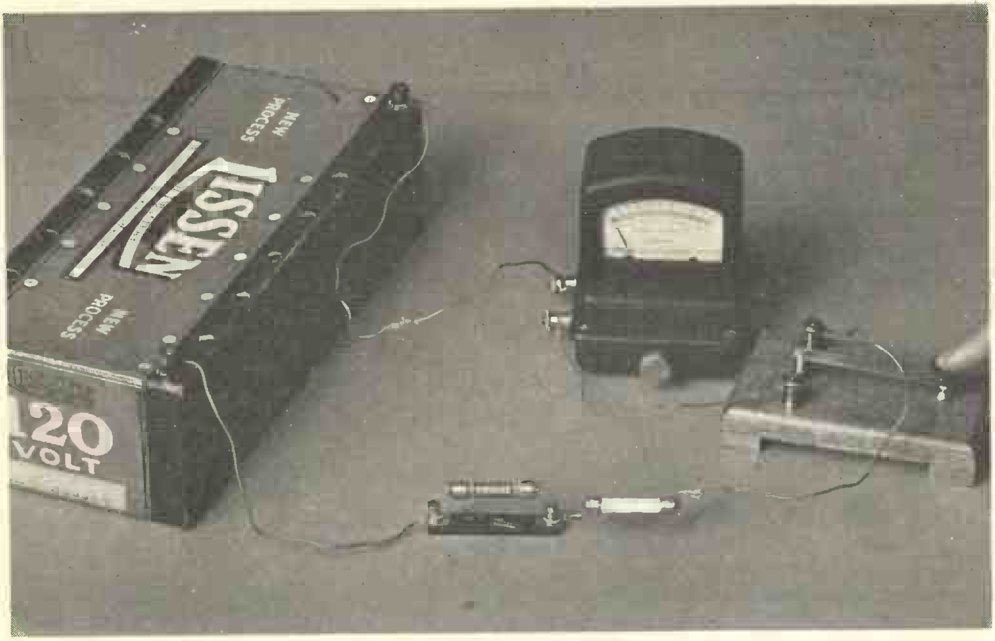


Fig. 20.—RESISTANCES IN SERIES AND IN PARALLEL.

Here the 2-meg. and 5-meg. grid leaks have been connected in series. Note that the reading is about 4½ degrees.

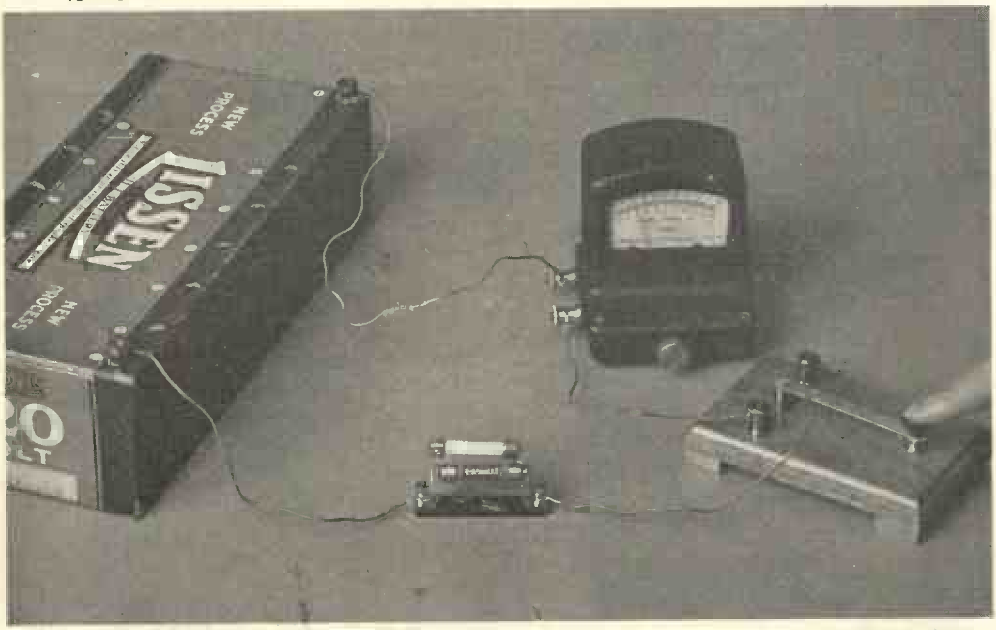


Fig. 21.—RESISTANCES IN SERIES AND IN PARALLEL.

Here the two grid leaks are connected in parallel. Note that the reading is about 21 degrees.

The full significance of these four pictures will be apparent when the calculation of series and parallel resistances is dealt with in a later section.

resistance (also called *resistivity*) of a material; there are other things to be taken into consideration and a large number of planetary electrons does not necessarily mean a correspondingly large specific resistance, but this variation in the number of planetary electrons explains sufficiently clearly why each material must have a specific resistance of its own.

How Specific Resistance is Measured

The specific resistance is usually measured across the opposite faces of a cube of material having an inch or a centimetre side, as shown in Fig. 14.

Unit of Resistance

The unit of resistance is one ohm (named after a German physicist G. S. Ohm) and this represents the resistance offered to the passage of electrons by *a column of mercury* 106·3 *centimetres in length and having a cross-section of* 1 *square millimetre, at* 0 *degrees Centigrade* (1 centimetre equals 0·3937 of an inch; a millimetre is a tenth part of a centimetre).

The resistance in question is that of a whole length of a conductor. The specific resistance which is measured across an inch cube or centimetre cube is much smaller and is measured in millionths of an ohm (microhms). The following table will give you an idea of what is meant.

Name of Material.	Specific resistance measured in microhms per centim. cube at 18° Centigrade.
Aluminium	2·94
Bismuth	119
Copper drawn	1·78
Copper annealed	1·59
Gold	2·42
Iron	12
Lead	20·8
Mercury	95·7
Nickel	11·8
Platinum	11
Silver	1·66
Tin	11·3
Zinc	6·1
Also	
Brass	6 to 9
Constantan	49
German Silver	16 to 40
Phosphor bronze	5 to 10
Platinoid	34·4

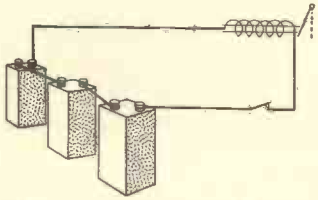


Fig. 22.—THE MAGNETIC EFFECT.

Electrons passing through a coil wound on an iron core will magnetise the core and the latter will attract a piece of iron.

Now, compare this specific resistance with the specific resistance of insulators:

Ebonite	2,000,000,000,000,000,000,000
Glass	100,000,000,000,000,000,000
Rubber	800,000,000,000,000,000,000
Marble	500,000,000,000,000
Mica	9,000,000,000,000,000,000,000
Paper	50,000,000,000,000,000
Paraffin Wax	3,000,000,000,000,000,000,000,000
Wood (dry)	50,000,000,000,000,000

The above shows at a glance why insulators do not allow the migration of electrons from atom to atom.

Some text-books take the specific resistance of silver as a standard, and express the specific resistances of all other materials as so many times that of silver. Thus, if the specific resistance of silver is 1·66, and is taken as unity, then the specific resistance of gold can be expressed as $\frac{2{\cdot}42}{1{\cdot}66}$ or 1·457 (no unit is attached to this number as it merely means so many times that of silver).

It is not recommended to use such comparative figures and the actual figure in microhms per centimetre or inch cube should be used for purposes of calculation.

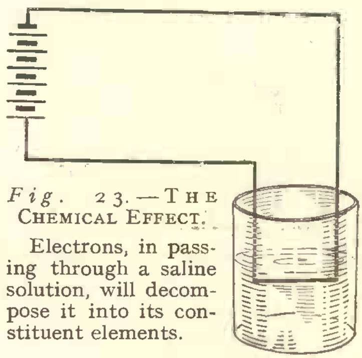


Fig. 23.—THE CHEMICAL EFFECT.

Electrons, in passing through a saline solution, will decompose it into its constituent elements.

Thus, when considering the resistance of a conductor we have first of all to discover the material it is made of and ascertain the specific resistance or resistivity of this material from tables. This will give us the resistance across the faces of an inch cube, *i.e.*, the resistance of a conductor having a length of 1 inch and a cross-section of 1 inch square. Since the opposition of planetary electrons becomes greater the more atoms are involved in this opposition, it is clear that the longer the conductor the greater its resistance. Therefore, if we have a conductor having 1 inch square cross-section, and a length of, say, 15 inches, we can find its resistance by merely multiplying its specific resistance by the length. If the cross-section is different from 1 inch square, the thicker the conductor, the less the resistance as the migrating electrons have more elbow room in a stouter conductor than a thin one.

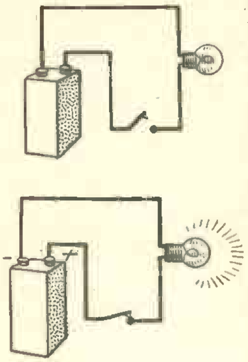


Fig. 24.—THE HEATING EFFECT.

(*Top*) When the circuit is broken, no flow of current takes place.

(*Bottom*) With the switch closed, electrons will flow from the negative terminal of the cell to the positive terminal, lighting up the electric lamp.

Finding the Resistance of a Conductor

In order to find the resistance of a conductor, we, therefore, take its specific resistance, multiply it by the length of the conductor, and divide by the cross-sectional area. So that

$$\text{Resistance} = \frac{\text{specific resistance} \times \text{length}}{\text{area}}$$

To make this short, let us put the letter R instead of resistance, the Greek letter ρ (pronounced roh) for specific resistance, the letter l for length and the letter a for area, then we can write briefly $R = \rho \times \frac{l}{a}$. Please remember that if you are using ρ, *i.e.*, specific resistance in microhms per centimetre cube your length must be also in centimetres and cross-sectional area in square centimetres. If the specific resistance is per inch cube, the length and cross-section must be expressed in inches and square inches respectively. Thus a copper conductor of 150 cm. length and 1·5 cm. sq. cross-section will have a resistance of

$$1{\cdot}78 \times \frac{150}{1{\cdot}5} \text{ or } 178 \text{ microhms.}$$

Series Resistances

When conductors are added end to end (series connection) their resistances add up, and the total resistance is the sum of the individual resistances (Fig. 15).

Parallel Resistances

When resistances are joined in parallel, as shown in Fig. 16, the final resistance is less than any single resistance. The calculation of this is a little complicated, and we shall deal with it when discussing the mathematics of wireless. The resistance of a conductor increases with temperature and this is the reason why in the table of the specific resistances the temperature at which the measurements were taken is stated.

Electric Current

The number of electrons migrating inside a conductor at each instant depends on two things: the E.M.F. or the voltage of the cell, and the total resistance of the circuit. Ohm has found the exact relation between these three items. He first used just one cell and gradually increased the length of the conductor constituting his circuit. He found that as the conductor length increased, the current diminished, and thus he discovered that *the greater the resistance of the circuit, the smaller the current*. His second step was to take a conductor of a definite length, and use one, two, three, four and five cells joined in series, so that the E.M.F. was larger and larger, and he found that with the same given resistance, *the greater the E.M.F. applied to the circuit the greater the current.*

In checking up on his results he discovered that in every case he could determine the value of current by dividing the E.M.F. applied to the circuit by the resistance of the circuit. Thus, with an E.M.F. of two volts, and a resistance of 1 ohm the current is 2 units. With an E.M.F. of 10 volts and a resistance of 5 ohms, the current is $\frac{10}{5}$ or 2 units. Similarly with an E.M.F. of 20 volts and a resistance of 2 ohms, the current is $\frac{20}{2}$ or 10 units. This Ohm's law can be written as Current $= \frac{\text{E.M.F.}}{\text{Resistance}}$, current equals the E.M.F. divided by the resistance. Putting instead of the word current the letter I (for intensity of current), the letter E for E.M.F. and the letter R for resistance we, can write briefly $I = \frac{E}{R}$.

As you see this is a very simple relation.

Amperes

The electrical current is measured in units called *amperes* (after a French scientist Ampère) and one ampere represents a flow of 10,000,000,000,000,000,000 or 10^{19} electrons per second past any point of the circuit. In wireless smaller units are used, viz., milliamperes, *i.e.*, thousandths of an ampere.

Heating Effect of Electrical Currents

In conclusion, let us note the three effects of electrical currents. When a current flows through a conductor the conductor becomes heated, and if the resistance of the conductor is sufficiently high, and the current sufficiently large, the conductor may become incandescent, as is the case with the filament of an electrical lamp. This is called *the heating effect* of electrical currents, and is due to the fact that migrating electrons which constitute the current in passing in sufficiently large quantities will accelerate the atoms and the molecules of the conductor, and by increasing their energy, will increase the amount of heat in the conductor.

The Chemical Effect

The second effect is *the chemical effect*, which manifests itself in that when an electric current passes through a saline solution in water, it will decompose the latter into its elements and will produce hydrogen and oxygen. In other solutions it will produce other products, but in every case it will cause a chemical action to take place.

This effect is utilised in electrolysis, and makes such operations as electro-plating possible.

The third effect is *the magnetic effect*, which is responsible for the production of a magnetic field around the conductor.

What this magnetic field is we shall learn from the next part of this work.

QUESTIONS AND ANSWERS

How Would you Connect a Number of Cells to give the Highest Possible Voltage?

In series, *i.e.*, the negative of one cell to the positive of the next and so on, leaving one positive terminal and negative terminal at either end of the battery.

How Would you Connect Cells to give the Highest Possible Current?

In parallel, *i.e.*, all the negatives to a common terminal and all the positives to a common terminal.

What is the Unit of Resistance?

The ohm, which is equal to the resistance of a column of mercury 106·3 cm. long having a cross section of 1 sq. millimetre.

What is Ohm's Law?

Ohm's Law may be stated as follows :—

Current in circuit $= \frac{\text{Voltage across ends of circuit.}}{\text{Resistance between ends of circuit.}}$

or $C = \frac{E}{R}$

Why is Copper chiefly used for Electrical Conductors?

Because it has the lowest specific resistance of any metal except silver, which is too expensive for ordinary use.

What Effect is Obtained by Joining two Resistances of, say, 2 Megohms and 5 Megohms in Series?

The equivalent resistance of the pair is 2 + 5 megohms, *i.e.*, 7 megohms.

PHOTOCELLS FOR THE EXPERIMENTER

By R. C. WALKER, B.Sc.

In this interesting article the general principles of photoelectric cells are first dealt with, and then an extremely simple, effective and inexpensive experimenter's set is described in detail. Many applications of these cells will suggest themselves to the reader with an ingenious turn of mind.

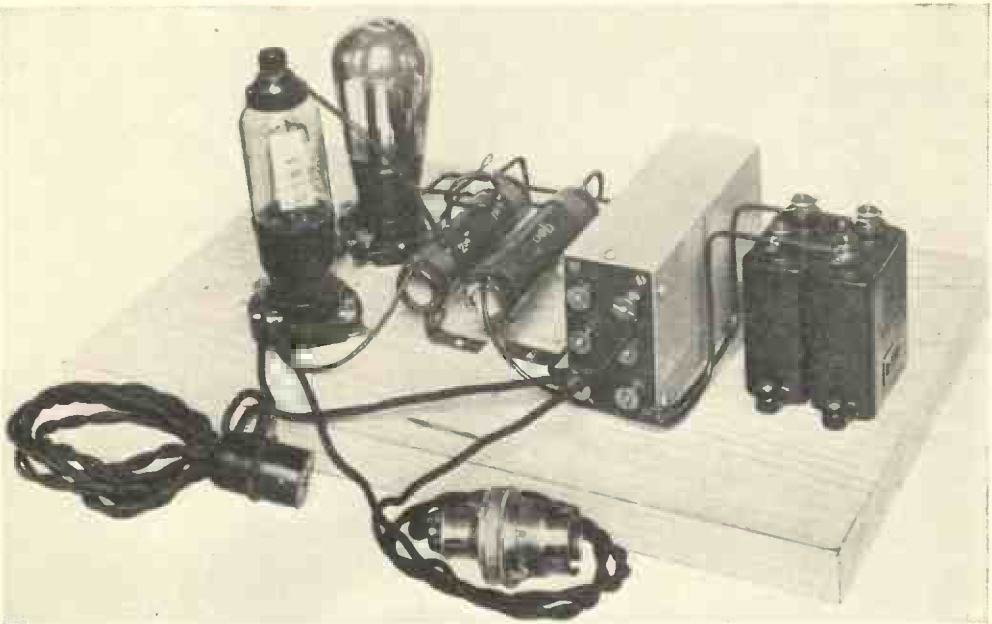


Fig. 1.—SIMPLE PHOTOELECTRIC CELL SET READY FOR USE.

This will enable the experimenter to perform automatically any operation that would normally be done by pressing a button or turning a switch.

DURING the last few years light sensitive cells have found so many applications in industry that we propose to deal here with some of the simpler circuits with which they are used, and illustrate various ways in which the experimenter can build his own apparatus and carry out interesting and instructive experiments which provide ample opportunity for ingenuity and inventive skill.

Modern Photoelectric Cells

The modern photoelectric cell, which is invariably of the type having a cathode or light sensitive surface of cæsium on silver oxide, is so much more robust and sensitive than the older potassium type, that it is quite within the ability of the practical man, given suitable components and understanding the simple fundamentals involved in the various circuits, to make and use a complete equipment of his own.

Effect of Light on Photoelectric Cells

The photoelectric cell is quite distinct from the selenium cell and other light cells of similar kind, inasmuch as light produces from the cathode an electron emission which resembles that which takes place from the filament of an ordinary wireless valve, though of course very much smaller.

Effect of Light on Selenium Cells

In the case of selenium and cells of a similar nature, the effect of light is to produce a change in the resistance of the electric circuit in which the cell is placed, and to cause the value of the current to alter in strength. The change in current produced in the case of the selenium cell is much greater than the emission produced by the same amount of light incident on a photoelectric cell, and in some of the more recently-produced cells no polarising voltage is required at all.

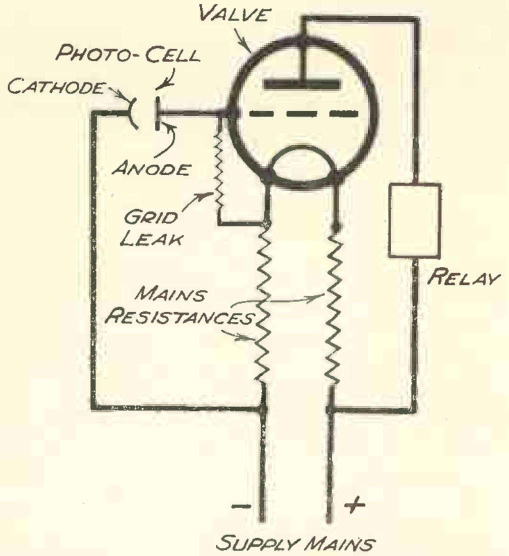


Fig. 2.—CIRCUIT DIAGRAM OF PHOTOELECTRIC CELL SET FOR OPERATING FROM SUPPLY MAINS.

Any small power valve having a high mutual conductance will be found satisfactory.

Why the Photoelectric Cell is generally more Satisfactory

These facts are, however, not such great advantages as would at first appear, and are outweighed by other considerations. For instance, some selenium cells are readily put out of action by shining a bright light upon them, and other types of cells requiring no batteries do not always permit the use of simple amplification. Taking all the facts into consideration, the photoelectric cell is the most satisfactory and reliable light cell available, and provided one or two essential points which will be dealt with later are attended to, the wireless enthusiast should have no difficulty in becoming fully conversant with its uses and enormous possibilities.

Fig. 4 shows an illustration of the Osram C.M.G.8. The cell is fitted with a standard valve base, to the anode pin of which is connected the positive electrode of the cell. The screw cap at the opposite end of the bulb forms the connection to the cathode or light sensitive surface. The cell bulb is filled with argon at low pressure, the presence of this inert gas enabling the emission to be greatly magnified and securing maximum sensitivity for operations involving simple detection of light variation.

CIRCUITS FOR PHOTOELECTRIC CELLS

The current obtainable from a photocell is usually not more than a few microamperes at the most, and frequently much less, but this small current is easily amplified with the aid of a simple wireless power valve or by means of a gas-filled relay—a comparatively new development. We will deal with these devices in turn and indicate several suitable circuits.

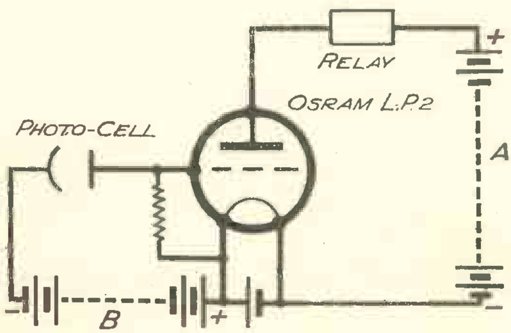


Fig. 3.—CIRCUIT DIAGRAM FOR WORKING SET FROM BATTERIES.

The battery A must be of high capacity if the set is to be operated for long periods, but battery B may be of small capacity.

How Amplification is Obtained with a Thermionic Valve

The thermionic valve is naturally too well known to need any description, and amplification of the photoelectric current is obtained by making the cell control the grid potential, either changing it from zero or positive value to a negative value, or *vice versâ*, according to the way in which the cell is arranged in the circuit. In the one case the change from light to darkness will cause the anode current of the valve to change from zero to about 10 ma., and in the other case the same change will take place in the reverse direction. If a sensitive relay is included in the anode circuit, this change in current through it can be made to operate any kind of electrical or mechanical device. The latter type of circuit is used a great deal in America but is not quite so sensitive as the former, so that we will deal here only with the most satisfactory circuit, though, as soon as the general principles are understood, the experimenter should have no difficulty in making up the alternative circuit.

Circuit Generally Used

Fig. 2 illustrates the circuit in which it will be noticed that the whole arrangement is designed to operate from supply mains. Actually any valve having a high mutual conductance can be used, such as the Osram L.P.2 or P.410, the latter being particularly suitable on account of its low filament consumption. The filament is connected in series with two resistances across the mains, the drop in volts across the right hand resistance providing the necessary anode potential for the valve, and the drop across the left hand resistance giving the polarising voltage for the photocell, the latter being connected between the negative main and the grid of the valve. The operation of the circuit is very simple.

Fig. 4.—AN OSRAM PHOTOELECTRIC CELL.

How the Circuit Operates

Let us assume that the photocell is at first kept dark, and that the right hand main is positive, the supply being D.C. A current of several milliamperes will flow in the anode circuit and will energise the relay. If a feeble light now falls on the cathode of the photocell, the electron emission will make the grid negative and will reduce the anode current to zero. This change in current through the relay causes it to switch on or off some external indicator. As soon as light is removed from the cell, the grid leak, which is of the order of 10 megohms, allows the charge to escape and the grid is restored to its original condition ready for the next impulse. One great advantage of this arrangement is that the circuit functions equally well without any alteration on alternating current supply provided the relay is a suitable one, and a condenser of about 4 mfd. is connected across its terminals. Under these circumstances, the valve and photocell act as their own rectifiers and utilise only the positive half of the wave. Of course, as an alternative in such a case, an indirectly heated mains valve and transformer could be used, but the cost of the latter is a consideration and the resistance circuit can be used on any type of supply.

Working the Set from Batteries

For the purpose of experiment, the whole set can be worked from batteries using a 2-volt valve, say the Osram L.P.2, and the circuit shown in Fig. 3 is the obvious modification. The battery A must be of high capacity if the set is to be operated for long periods, though B need be only of small capacity as the current taken by the photocell is negligible.

HOW TO MAKE A SIMPLE SET

Fig. 1 shows a kit of parts mounted ready for use, and Fig. 5 the outline of convenient positions for the various components. This is an extremely simple, effective and inexpensive home constructor's set which will provide hours of amusement to the experimenter and will enable him to perform in his own home any operation which would normally be done by pressing a button or turning a switch, except that in this case the whole business is made automatic.

An Important Point

It is not essential that the layout of the components should be exactly that shown in Fig. 5, but to avoid failure or indifferent

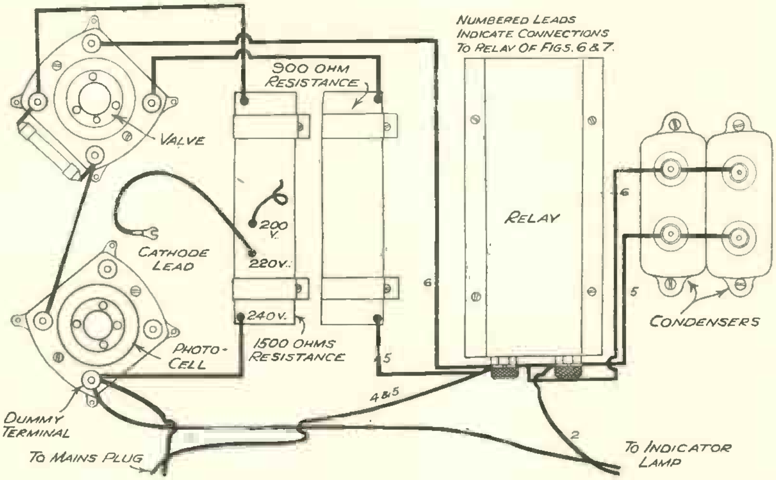


Fig. 5.—Diagram showing Convenient Positions for the Various Components of the Photoelectric Cell Set.

The connection from the anode of the photocell to the grid of the valve should be as short as possible and should be clear of any other leads.

operation, the user should see that the connection from the anode of the photocell to the grid of the valve is as short as possible and should be clear of any other leads. This is particularly so where the supply used is A.C. The valve and photocell are always preferably mounted together, these two components then being placed at any reasonable distance from the rest of the set.

Hints about Wiring

To facilitate the process of wiring up, it is best to use tinned copper wire, a good length of which should be straightened out by fastening one end in a vice and stretching so as to remove all the kinks. After cutting into convenient lengths, a loop should be made at one end by gripping with a pair of round nosed pliers. The length of wire should then be covered with insulated sleeving, leaving just enough bare wire to make a similar loop at the other end. No bare wires must appear or damage will almost certainly occur by accidental contact during experiments. The ends of the loops of wires should be placed under the nuts so that the latter, when tightened up, tend to close the loop.

Soldered joints are not necessary, though if the user finds that the set meets his particular requirements in a certain direction it would be desirable to build up the circuit in a substantial housing.

Adjusting the Set

It will be noticed from Fig. 5 that the two resistances are of unequal value, being 900 ohms and 1,500 ohms, the latter being tapped at 1,100 and 1,300 ohms, these being suitable values for a 0·1 amp. filament valve, such as the P.410. To secure the highest sensitivity, the resistances should occupy the positions shown in Fig. 5, the tappings being used for 200, 220, or 240 volts, according to the supply. If not already working on the 200-volt tapping, the cathode may be connected to the next lower tapping if such high sensitivity is not required. It is not necessary to use a bright light to work the set; in fact, too bright a light may cause a discharge, visible as a blue glow, to pass in the cell, and although this will not do any harm if only momentary, it will, if allowed to pass for any period, damage the cell permanently. Care should be taken therefore to reduce either the voltage or the intensity of the light on the cell if at any time the glow discharge appears.

Screening the Cell from Daylight

In order to screen the cell from daylight, a piece of cardboard tube about 1½ inches in diameter and 4 inches long, closed at one end and having a rectangular window cut opposite the position of the cathode of the cell, can be made to fit closely over the bulb. By turning this tube round the area of the cathode exposed can be varied, and the arrangement used as an adjustable diaphragm so as to put the set in its most sensitive state.

Testing the Set

After carefully checking the wiring according to Fig. 5, which is a diagrammatic circuit of the components shown in Fig. 1, remove the photocell and connect the plug into a lamp-holder on the house supply and switch on. If the circuit is correct, by carefully listening, the relay will be heard to close with a click, and the lamp will light up. If not, either the circuit has been wrongly wired or, if the supply is D.C., the polarity is wrong. In the latter case, no damage will have been done, and the plug merely needs to be reversed in its holder. The same thing may, of course, occur with battery operation.

Connecting up the Photocell

When this has been put right, the photocell can be connected up and the circuit tested by shining a hand torch on the cell when the relay will go in and out. This arrangement can be used for counting people coming in and out of a building, or as a burglar alarm, as will be described later. If it is desired to operate the circuit in the reverse direction, that is for the indicator to come on when the cell is illuminated, it is only necessary to use terminals 1 and 3 instead of 2 and 4.

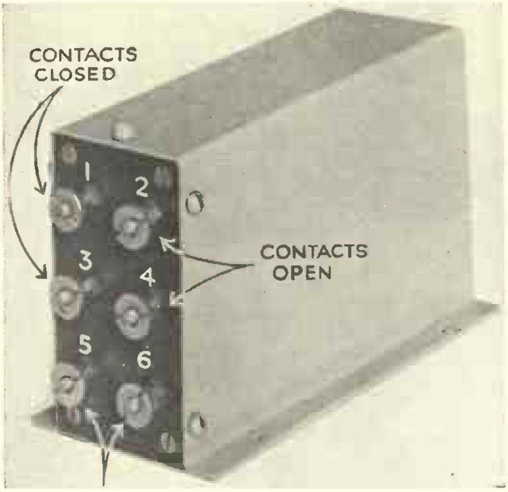


Fig. 6.—EXTERNAL CONNECTIONS OF RELAY.

The Relay

Reference should here be made to Fig. 6, which shows the external appearance of the relay and to Fig. 7, which shows the internal connections. Terminals 5 and 6 form the ends of the operating coils of the relay, contacts 1 and 3 are closed when the relay is out of circuit, and contacts 2 and 4 are open under the same conditions. So far we have only used one pair of these at a time, but by using both in the same circuit several modifications of the arrangements can be made.

A Useful Burglar Alarm Circuit

First of all, the circuit of Fig. 5 can be modified to that of Fig. 8. Here we have included in the anode circuit a switch which must be closed when the set is ready for working. The photocell connection to the negative main is now made through contacts 1 and 3. A little consideration will show that, provided the switch S is closed, immediately the coil of the relay

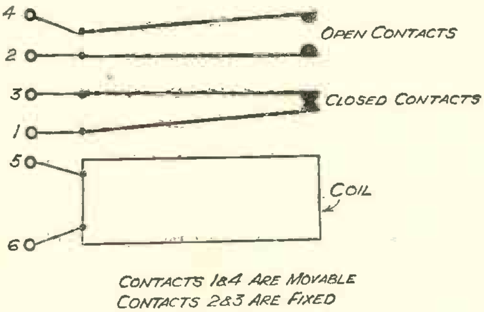


Fig. 7.—INTERNAL CONNECTIONS OF RELAY.

is energised, the photocell circuit is broken by the opening of contacts 1 and 3, so that the light cell is switched out of circuit, and the normal anode current will continue to hold the relay closed whether there is light on the cell or not until the switch S is opened, which will restore the set to its original condition. This circuit is very useful, for instance, for a burglar alarm, because if the lamp is substituted by a mains bell, then immediately the intruder passes across the exciting beam, the alarm will ring and continue to do so until reset by the switch S.

Avoiding Insulation Leakage

The experimenter will have noticed that the photocell connection is broken on the negative main side and not on the valve side. This illustrates a point previously mentioned, namely, that the wiring between cell and valve should be as short as possible. In this case it also avoids the possibility of insulation leakage.

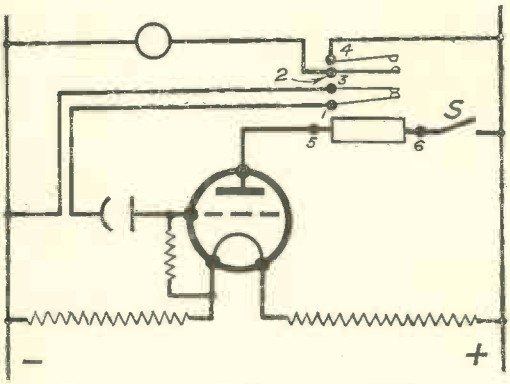


Fig. 8.—How the Circuit can be Used for a Burglar Alarm.

This is a modification of the circuit shown in Fig. 5.

Race Timing

This arrangement is also extremely useful in such applications as race timing, where the stop clock is an electromagnetically-operated instrument and is stopped by the passage of the first competitor across the winning line. In such a case the interruption of the exciting beam is usually too rapid for the clock mechanism to have time to pull in, but, by allowing the photocell to be removed from the circuit as just described, the stoppage of the clock is positive. The slight lag in its operation is practically a constant and can be allowed for. This is an application of photocells where the use of light rays gives an accuracy considerably greater than is possible by the ordinary method of timing by hand.

The Next Modification

The next obvious modification is that of using the last circuit the reverse way round, that is to keep the cell normally dark and to bring the alarm into action continuously as soon as light falls on the cell. A number of useful applications of this circuit will immediately suggest themselves. For instance, it could be used to give an alarm as soon as the lights were turned on in a room, or again, if a chest or cupboard were opened and exposed to daylight. As an alternative form of burglar alarm, this would be particularly effective, since the intruder, on hearing the bell sound, would naturally turn the lights out again, but, of course, all to no purpose, since once started, the alarm will sound continuously. The method of wiring this arrangement is shown in Fig. 9. In order to set the circuit for light detection, the photocell must of course be made dark before the switch S is closed, and the position of the latter should be away from the main amplifier and in a position known only to those in authority. After closing S to set the circuit, it must be opened again when ready for detection.

How Currents of any Magnitude can be Controlled

All these instances could be elaborated almost indefinitely, but it must be remembered that the telephone type of relay, which is the kind here described, has only small contacts and is usually not intended to carry more than about 0·25 amps. in circuits where the load is non-inductive. To control larger currents requires the addition of extra switchgear which must be excited through the telephone relay contacts. In this way, currents of any magnitude can be controlled and the load is limited only by the current-carrying capacity of the switchgear employed. It is possible also to add extra contacts to the relay, and provision is made for this in its construction, so that several independent circuits can be brought under control of one photocell.

Using Two Complete Amplifier Circuits

By using two complete amplifier circuits a number of ingenious arrangements can be made by interconnecting the various relay contacts. For instance, it is obvious that if two light beams are arranged across a passage, the interruption of the first can be made to put on an advertising sign, whilst the interruption of the second can be made to extinguish the sign. In addition, it is possible to make one photocell act as a selector to the other, so that objects passing through the exciting beam are recorded only when they pass in one direction, according to which photocell is obscured first, and so on.

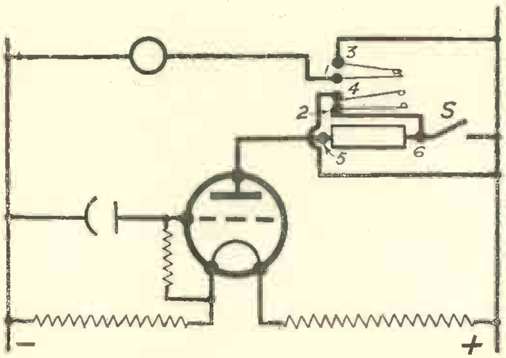


Fig. 9.—How to Set the Circuit for Light Detection.

In this case the circuit shown in Fig. 8 is used the reverse way round, that is to keep the cell normally dark and bring the alarm into action continuously as soon as light falls on the cell.

THE GASFILLED RELAY

Instead of a wireless valve, it is sometimes an advantage to use a gasfilled relay in conjunction with a photocell. The gasfilled relay is a comparatively new development, and it is quite impossible here to go into its description and uses very deeply, though used as a simple switch with a photocell it will interest the more serious experimenter. In appearance it resembles an A.C. indirectly heated mains valve, and is mounted on a standard five-pin valve base. In addition to the heater, cathode, control grid and anode, the bulb contains mercury vapour so that it is really a hot cathode mercury vapour rectifier with a control grid.

Discharges

If the D.C. potential applied to the anode does not exceed 15 volts, the relay behaves just like an ordinary wireless valve, but if the anode potential is greater than this value, and the grid voltage is zero, then a discharge will pass in the anode circuit, the magnitude of this current being limited by a resistance to prevent permanent damage to the tube. Negative grid voltage will prevent this discharge from passing, and for every value of anode voltage there is a corresponding critical value of negative grid voltage which will just prevent the discharge from starting. Once the discharge has started, no increase in grid voltage will have any effect and the anode current can only be stopped by breaking the anode circuit or by reducing its potential below 15 volts.

Trigger Action

The tube therefore functions by trigger action of the grid potential, which can obviously be controlled by a photocell, as shown for example in Fig. 10. Here the arrangement is set for detection of light and the grid potential adjusted so that it is just below the critical negative value for the given anode voltage when the cell is dark. When light falls on the cell the grid becomes less negative until the discharge passes.

Advantage of Gasfilled Relay

Obviously the great advantage of this type of tube over the valve is the large value of the anode current which permits the use of a robust relay direct in the anode circuit. In addition, in the case of the example cited, it is easy to detect light flashes of very short duration, since the time for which the grid must be reduced below the critical value to start the discharge is very small and may be as low as 1/1,000 sec. No relay with a movable armature would be able to pull in in such a short period. The Osram G.T.1 type has a heater voltage of 4 and current of 1·3 amps, the maximum anode current being 300 milliamps. It is possible, by using A.C. on the anode, to secure continuous control just as in the case of the wireless valve, since the arrangement is self-resetting during every half cycle of the alternating current.

Using Photocells for Making Measurements

We have now given a brief outline of the methods of using photocells with amplifying tubes so as to detect light or darkness and so actuate some mechanism by means of a relay. Most of the important applications in industry involve one or other of the circuits so far described. No mention has been made of the use of the cell for making measurements because, although it is frequently used in this way, as for instance in giving a chart record of the smoke density in a chimney stack, the amplifier circuits involve a number of refinements outside the range of the average experimenter who is not usually equipped with a sensitive reflecting galvanometer necessary for making direct measurements without amplification. We will only state here that, under suitable conditions, the photocell can be very useful for actual measurement of light intensity, of the absorbing power of translucent solids and liquids, and for the comparison of colours in dyes and fabrics.

Invisible Rays

The cæsium silver oxide cell is responsive to the shorter infra-red rays which lie just beyond the limit of visibility, and, in consequence, by the use of a suitable filter which will cut out the visible rays from the light source, it will be practically impossible to detect the light source. A thin piece of ebonite forms a convenient screen. This, of course, cuts off much of the useful light, so that the range over which the set will now work is considerably reduced. In most cases it is not necessary to make the beam absolutely invisible, and a screen of ·006 inch will make the beam a dark red, which can only be seen by looking directly in the line of projection. The best form of illuminant consists of a 6- or 12-volt car head or side lamp, with a double convex lens about 3 or 4 inches in focal length, so arranged to produce an image of the filament on the cathode of the cell. If A.C. supply is available, it is, of course, easy to run the lamp from the mains through a transformer. This kind of lamp is one which an experimenter can rig up in a few minutes. It is simplest to focus the lamp on the cell before inserting the screen in front. Together with the circuit of Fig. 8 this arrangement can be used as a burglar alarm.

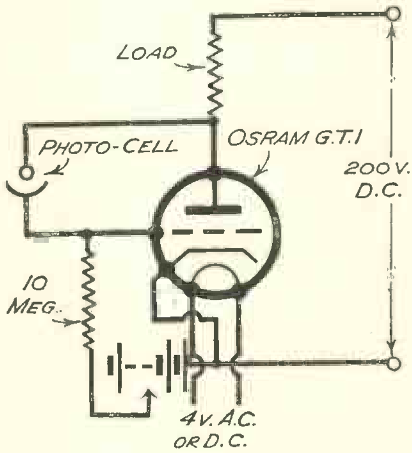


Fig. 10.—Circuit for Detection of Light.

The grid potential is adjusted so that it is just below the critical negative value for the given anode voltage when the cell is dark.

GENERAL APPLICATIONS

Mention has been made of the use of the photocell for simple counting in cases where the objects in question are of various sizes, of different shapes, varying widely in weight or otherwise, of such a nature that the light beam and photocell is the only satisfactory method of recording them. Naturally, selection of objects according to size is frequently simple. For instance, if the exciting beam is arranged at a specified height, only those objects exceeding this height will be detected and subsequently selected, if necessary, mechanically.

Control of Illumination

The control of illumination by daylight or darkness is another instance of great utility. Not only is it applicable to factory lighting, where the manufacturing output may suffer if the lighting falls below a certain value, but it has a field of usefulness for the control of advertising signs, since the user can ensure that his sign is on only when it is dark enough for it to be effective and its advertising value a maximum.

Novel Advertising Attractions

Turning now to the realm of advertising, it is clear that the shopkeeper will find the photocell exceedingly useful and of enormous assistance to his sales. Novel attractions, in which the cell can be used to produce mystic effects, will always secure great popularity. An arrangement which has had much publicity for shop-window advertising consists of a small ornamental box containing two compartments, the lower one housing a lamp and the upper one a photocell. The circuit used is that shown in Fig. 5. When this box is hung in a window, sufficient light is reflected from a person's hand to operate the cell circuit so that observers in the street can put on an illuminated display in the window or set a figure in motion. This is a simple piece of apparatus which anyone can make up. Care has to be taken that stray light does not reach the photocell and so keep the display permanently on. The only object of using reflected light is that the equipment will work either in daylight or darkness. If the window in which the set is to be displayed is near an outside lamp it may be better to operate the arrangement by direct light, using the hand to interrupt the light reaching the cell.

An Alternative Arrangement

Alternatively, the cell can be concealed within the article to be advertised. In one typical instance the cell was fitted to the interior of an empty valve carton in which the outline of the valve had been cut out to provide a window through which the general lighting of the surroundings passed on to the photocell. Several illuminated neon signs could be switched on by the observer who passed his hand over the carton. Such devices never fail to attract a crowd. Another attraction which causes a good deal of amusement consists of a dummy rifle, in the barrel of which is fitted a small lamp with a diminutive optical system, the lamp circuit being closed through the trigger of the gun. The photocell is fitted behind the bull's-eye of the target, this portion being transparent, so that whenever the competitor spots the bull's-eye the bell rings.

Controlling Small Model Motor Cars

The experimenter will have already guessed that it is fairly easy to use the cell for the control of small model motor cars or boats by means of a hand torch, provided they are large enough to accommodate the amplifying circuit. They can be stopped, started or reversed by this means of control. It is also possible to construct a small motor car which will respond to traffic signals and stop when a beam of light from the sign post shows red. These examples are sufficient to show the enormous scope for light sensitive cells in advertising.

Smoke Detection

The utility of the circuits previously described for smoke detection should not be overlooked, as this is an important application. Not only is it useful to the engineer for prevention of smoke in his boiler flue with a view to avoiding the pollution of the atmosphere, but it is exceedingly useful as a fire detector. A serious fire is almost always preceded by great quantities of smoke, most of which collects near the ceiling of a room or warehouse. The simplest circuit and lamp will provide a really good fire alarm.

Adjusting the Aperture over the Cell

The only point which needs attention is the aperture over the cell. This must, of course, be adjusted so that the relay is almost on the point of closing, so that the slightest obstruction will operate the alarm. An adjustable diaphragm is the best thing for this purpose, but this is usually rather expensive. Otherwise a trial can be made with apertures of various sizes in pieces of sheet metal.

SHORT WAVE BROADCASTING

By NOEL ASHBRIDGE, B.Sc., Chief Engineer, B.B.C.

In this interesting article Mr. Ashbridge summarises present-day knowledge on the possibilities of short waves and very short waves for broadcasting. An account is also given of the methods which have been tried for overcoming fading.

SHORT-WAVE broadcasting differs in many ways from broadcasting as generally known by the great majority of listeners, and even in these days of advanced technique it is not possible to ensure anything like the same excellent service on short waves that can be given on medium waves. This point is mentioned at the outset, because there seems still to be considerable misconception on this subject. In the course of this article an endeavour will be made to show why this is true, and at the same time to indicate the possibilities of short-wave broadcasting in spite of this limitation, when all the various technical factors are taken into account and are exploited to proper and reasonable limits.

How Wireless Waves are Classified

First of all, let us consider what is meant by the terms "short waves" and "long waves." It is well, perhaps, to define the limits of wavelength in the various categories in accordance with the recommendations of the International Consultative Committee for Radio-electric Services, as follow :—

Waves above 3,000 metres (below 100 kc/s.) . .	Long waves
Waves between 200 metres and 3,000 metres (between 1,500 and 100 kc/s.)	Medium waves
Waves between 50 metres and 200 metres (between 6,000 and 1,500 kc/s.) .	Intermediate waves
Waves between 10 metres and 50 metres (between 30,000 and 6,000 kc/s.) .	Short waves
Waves below 10 metres (above 30,000 kc/s.) .	Very short waves

Direct and Indirect or Reflected Radiation

These limits were not chosen arbitrarily, as perhaps it may seem at first sight, for the divisions correspond roughly to the points at which the methods of transmission used in practice change, according to whether it is more advantageous to make use of the direct or indirect radiation. There is, of course, no entirely abrupt change at any one point, and practically all waves, except the very short ones, are propagated under certain conditions both by means of the direct and indirect ray. However, certain wavebands are more suitable for transmission by the one method than the other.

Thus, long waves can be used to transmit over long distances by direct ray transmission, and are, therefore, less affected than the shorter ones by changes of time of day and season.

Similarly, medium waves are used mainly for direct-ray transmission, but in this case the indirect ray plays a more important part, not usually in assisting normal transmission, but rather in producing fading effects.

Intermediate waves are used for both methods of transmission, while short waves are normally used only for indirect ray services over long distances.

Very short waves are only suitable for direct-ray short distance transmissions, where there is almost a clear optical path between the receiving and transmitting aerials, but this would probably be a more correct statement were the limit placed at 8 metres instead of 10 metres.

Why Short Waves are used exclusively for Long-distance Broadcasting

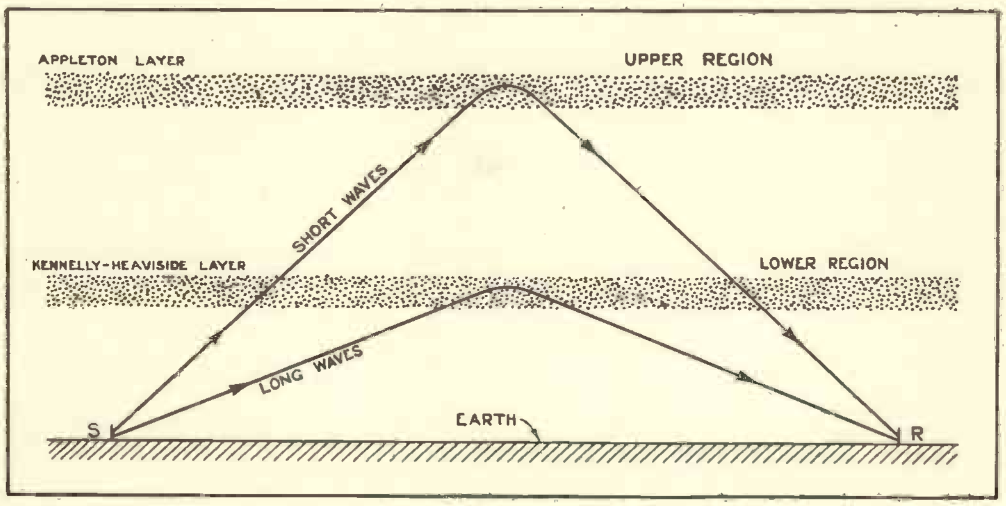
However, we are here concerned almost entirely with short waves, because the only other waveband which can be considered for transmitting over long distances, namely from 3,000 metres upwards, is not practicable for broadcasting on account of the very high powers which it would be necessary to use for direct-ray transmission over such distances. In addition there is the even more important difficulty that the width of band occupied by a broadcast transmission is far too great to accommodate any appreciable number of stations in the long-wave band. It is for this reason that there are no channels allotted to broadcasting under the Washington International Convention in this band, and the only wavelengths reserved for long-distance broadcasting are in the short-wave band, as follows :—

Kc/s.			Metres.		
6,000	to	6,150	50	to	48·8
9,500	,,	9,600	31·6	,,	31·2
11,700	,,	11,900	25·6	,,	25·2
15,100	,,	15,350	19·85	,,	19·55
17,750	,,	17,800	16·9	,,	16·85
21,450	,,	21,550	14	,,	13·9

The principal difference between broadcasting on medium waves and on short waves is that in the case of the former we rely mainly on the direct ray, which is propagated over the surface of the earth, while on short waves we use entirely the indirect, or space ray, which is propagated at an angle to the horizontal and is received only after reflection by or refraction in an ionised layer above the earth's surface.

Why Medium-wave Reception Improves after Dark

As already mentioned, with medium waves there is also an indirect or space ray which interferes with the direct ray and causes fading at a certain distance from the transmitter, and in fact limits at night the so-called " service area " of a station. This indirect ray on medium waves also gives reception of a station at distances beyond that at which it is receivable by direct ray, and although fading is generally less than where the two rays interfere mutually, yet it is present, and furthermore reception by indirect ray is only possible after dark.



REFLECTION OF LONG & SHORT WAVES. (APPLETON)

Fig. 1.—A Graphical Representation of Transmission by Reflection from the Kennelly-Heaviside and the Appleton Layers.

Skip Distance in Short Wave Working

On the short waves there is also a direct ray, but this is attenuated very rapidly over the surface of the earth, and it is not generally receivable beyond a relatively short radius. It results, therefore, that there is a zone round a short-wave transmitting station in which it will not be receivable, for the direct ray becomes highly attenuated before the indirect ray reaches the earth after reflection, at any appreciable strength. This zone is called the "skip distance," and will vary in extent and distance from the transmitter, according to the wave in use and the time of day and season of the year. The skip distance increases as the wavelength is decreased, and for a given wave is greatest at night in mid-winter.

It also follows that a wave which is suitable for transmission over a certain distance at a certain time of the day and season of the year may not be suitable for a different distance at the same time of the day or year, or for the same distance at another time of the day or year. Hence it will be seen that the necessity arises to transmit on several wavelengths in any scheme for Empire broadcasting, in which it is desired to transmit from this country to points situated almost all over the earth's surface.

A Puzzling Fact

Before dealing, however, with the B.B.C.'s Empire broadcasting scheme, it is desirable to consider a little more fully the more fundamental points in short-wave working. It has been stated that while the indirect ray is not reflected to any extent in medium-wave transmission during daylight, yet it is reflected in short-wave transmission. It might appear at first sight that the Kennelly-Heaviside layer is a more efficient reflector of short waves than of medium waves, but calculation shows that the long and medium waves should be reflected better than the short waves, assuming that the height of the layer is about 100 kilometres, and that all waves are reflected *at this height*. However, it is well known that in practice short waves are more effective for indirect ray transmission over long distances than medium or long waves.

Professor Appleton's Solution

As long ago as 1927, Professor E. V. Appleton, F.R.S., of King's College, London, pointed out that a solution of the problem would be to assume that the short waves are reflected at much higher levels in the upper atmosphere than the medium or long waves, and experimental work carried out since then, both in this country by Professor Appleton, and in other countries, has produced good evidence that this indeed takes place. It is now postulated, therefore, that there are two reflecting regions—one, the lower or Kennelly-Heaviside layer, situated at about 100 kilometres above the earth's surface and reflecting the long and medium waves, and another, the Appleton layer, situated at about 230 kilometres above the earth's surface, and reflecting the short waves.

According to Appleton, the Kennelly-Heaviside layer offers considerable absorption to short waves as they pass through. The strength and constancy of a short-wave transmission depend, therefore, on changing conditions in two layers—variable attenuation of the lower layer and variable reflection in the upper layer. In any case it is true that great variations in strength of the received signal take place in short-wave transmission, which produce not only slow fading over a period of minutes, but also, on occasions, high-speed fading which may spoil the quality of a broadcast transmission. In addition, selective fading may take place, this being caused by a differential propagation of the carrier wave and the side bands. This also results in distortion of speech or music. As these results are produced by changes in the reflecting layers over which we have no control, it becomes obvious that it is difficult to specify that a given short-wave transmission will be well received at any given time. All that we can do is to take account of available experimental evidence that points to the greatest probability of success, and to hope for the best.

Selecting the most Suitable Wavelength

Practical experience, however, gives us quite a lot to go on, and the wavelengths most suitable for given distances, at given times of day and seasons of the year, are by now fairly well established. The most suitable wavelength does not seem to remain constant from year to year, however, but changes gradually in a cycle of several years' duration. It is thought that this cycle is determined by solar activity, although the exact relation is

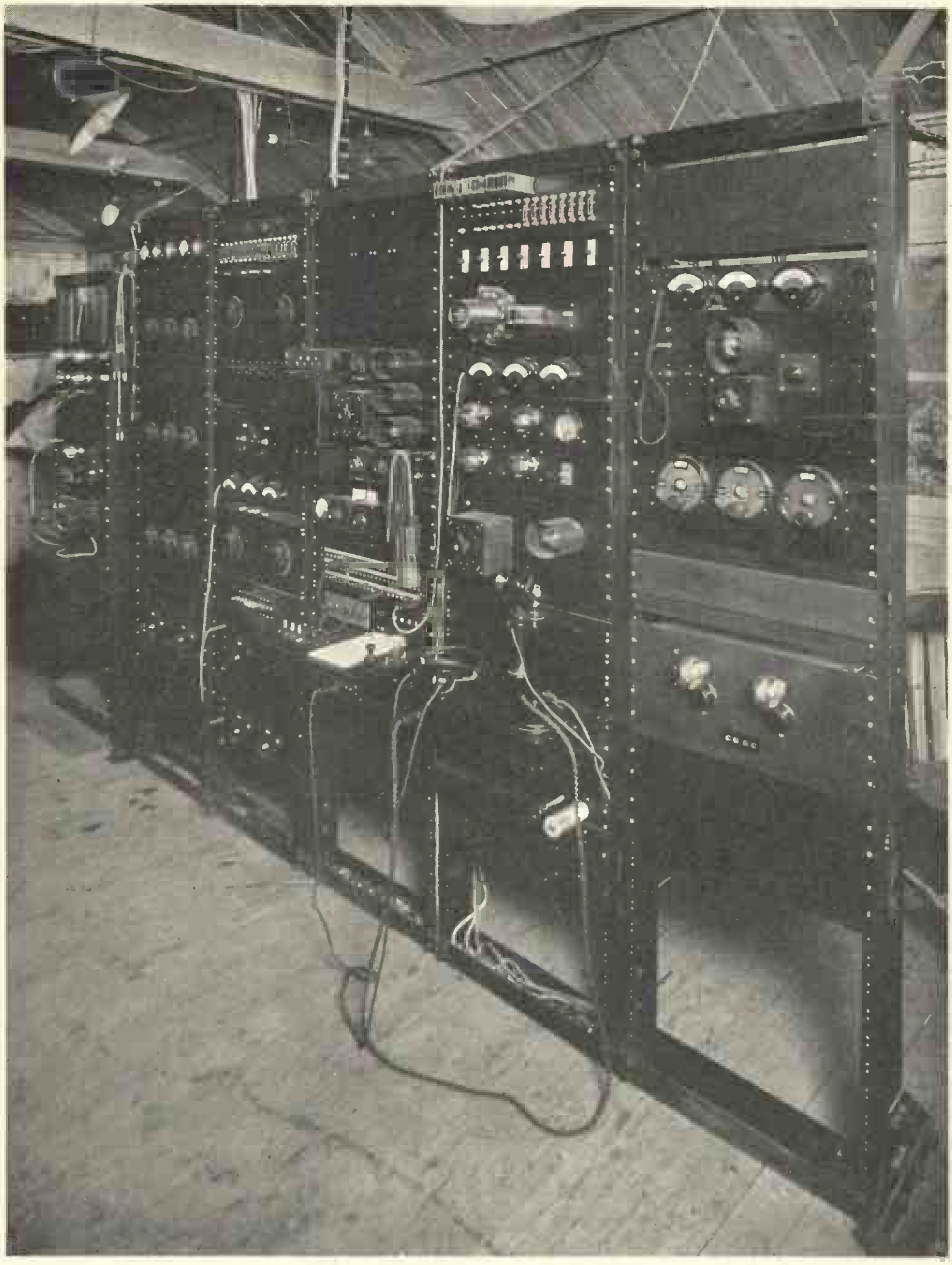


Fig. 2.—Experimental Short Wave Receiver.
For " spaced " aerial reception using three aerials.

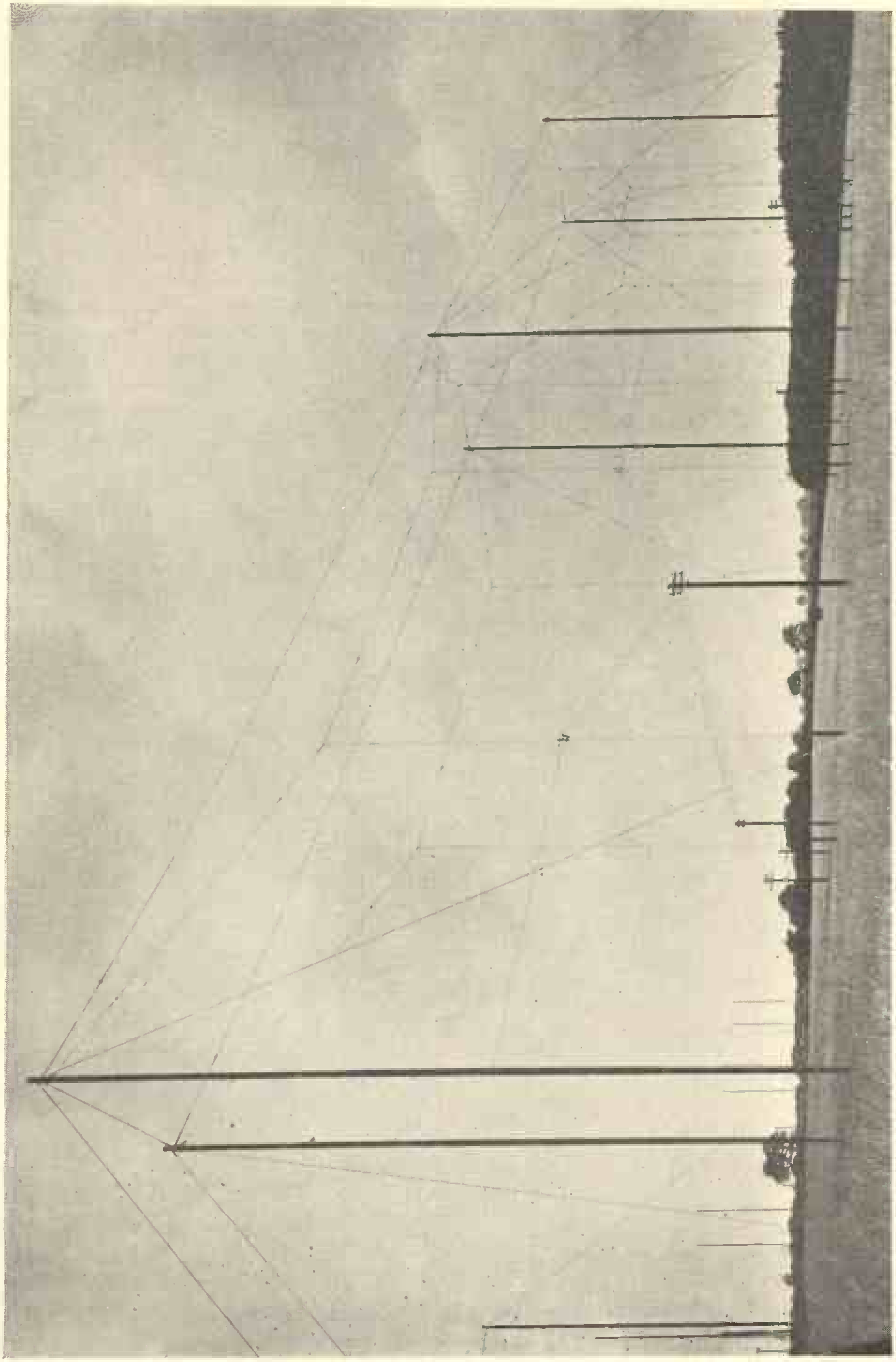


Fig. 3.—Aerials for Empire Short Wave Broadcasting erected at Daventry.
Showing the South African zone and part of the India zone in the left background.

not yet certain. Again, comparatively short periods of bad reception are usually considered to be due to the existence of magnetic storms.

Methods of Ensuring Good Reception on Short Waves

Having chosen the most suitable wavelength, it becomes necessary to examine what can best be done to ensure the best chances of reception. We know that we must expect fading and generally some distortion, but can we do anything to minimise its effect at the receiving end? In a short-wave broadcasting system, such as the B.B.C.'s Empire broadcasting scheme, there are two distinct conditions that may obtain at the receiving end. Firstly, reception may be carried out directly by the listener, and, secondly, reception may be carried out by some central organisation, the received programme being relayed through a normal medium-wave broadcast transmitter to local listeners.

In the former case, which will obtain in the Colonies where no local broadcasting service exists, or in remote parts of the Dominions unserved by the local broadcasting network, the receiver must of necessity be simple to operate and not too costly.

In the latter case, however, there is generally the possibility, both financially and technically, of erecting a much more elaborate receiving station. The question arises, therefore, as to what should be the characteristics of such a station, for experiments have shown that much can be done to achieve greater reliability by the use of special receivers?

Simultaneous Transmission on Two Waves

It was suggested at one time that it might be of material advantage to use two transmitters simultaneously radiating the same programme on two different short waves. Each transmitter would be received on one receiver and the outputs combined, and in this way it was hoped to minimise fading. However, this procedure has the great disadvantage that two waves are necessary for one transmission, and there is already considerable congestion in the short wavebands. In practice, the procedure was not found to be as useful as might be expected, because if the waves were close together and one was affected by bad fading, the other was likely to be similarly affected, while if they were far apart then the conditions of propagation were, in general, so dissimilar that the two waves could not, with advantage, be used simultaneously.

Reception by Spaced Aerials

A more promising arrangement appeared to be to have two receivers, each with its own aerial tuned to the same transmitter, and to arrange that the receiving aerials were some distance apart. Fading on these so-called spaced aerials was generally not simultaneous, and by combining the outputs of the two receivers, it was possible on occasions considerably to improve reception conditions. Experiments were carried out in this country by the British Broadcasting Corporation and Marconi's Wireless Telegraph Company, and in America by the National Broadcasting Company and the Radio Corporation of America in co-operation, to investigate the practical utility of this system.

Reflector and Collector Aerials—The Beam System

Whether or not "spaced" or "diversity" aerials (as they are called in England and in America respectively) are used, there is also an advantage in using reflectors (*i.e.*, beam reception), both for transmission and reception, from the point of view of keeping the ratio of wanted signal to unwanted noise high. In other words, the noise level can be kept lower although, of course, the use of reflectors does not, in itself, necessarily reduce fading. It will be realised that the use of special aerials will generally mean that an aerial system will be needed for each wavelength to be received, as the dimensions of such aerials bear a fixed relationship to the wavelength in use.

Automatic Gain Control

A third way in which the reception of short waves can be improved is in the provision of some form of automatic gain control in the receiver. Indeed, this is really the first point which should receive practical consideration in a short-wave receiver, for such a device can, of course, be used irrespective of the type of aerial employed.

There are several forms of automatic gain control in use, but they all work on the principle that as the strength of the received carrier wave becomes smaller, the gain of the high-frequency circuits of the receiver is increased, and *vice versâ*. In this way, slow-speed fading can be dealt with quite satisfactorily, although in the case of broadcasting some slight measure of distortion is inevitable. The fact that fading is taking place is indicated by a rising and falling in the noise level instead of by a rising and falling in the strength of the received signal.

Automatic Gain Control will not deal with High Speed or Selective Fading

It is necessary, however, in order to preserve good quality, to arrange that the automatic gain control has a time constant which is large in proportion to the duration of one cycle of the lowest modulation frequency to be received, and it follows, therefore, that such a device will not deal with high-speed fading or selective fading. Selective fading cannot be eliminated satisfactorily at the receiving end, but considerable advantages are claimed for the single side band system of transmission, in this connection. However, this does not at present seem a possibility for short-wave broadcasting, as reception can only be carried out on special and complicated receivers.

THE EMPIRE BROADCASTING SCHEME

In conclusion, mention must be made of the B.B.C.'s Empire broadcasting scheme, indicating rather the general lines on which it has been designed than the details of its execution.

Wavebands Available

In the first place, it was desired to provide the best possible reception in the various parts of the Empire at some period between the hours of 6 p.m. and midnight, local time, although it was desirable to ensure that transmissions could be made at other times if special occasion arose. The wavebands available are those stated at the beginning of this article, and specific wavelengths, one in each of four bands and two in each of the other two bands, have been registered for the station.

The Five Zones to be Covered

The next question which had to be decided was whether effective use could be made of directional transmission. An examination of a globe map of the world showed immediately that the extreme limits of the Empire subtend a very wide angle at this country. It followed that the use of one single-directional aerial was out of the question, quite apart from the fact that a directional short-wave aerial is normally designed for one particular wavelength. In any case, therefore, at least eight such aerials would be required. However, examination of the map also showed that from a transmission point of view, the Empire could be divided up into five zones, the boundaries of these zones being determined by the factors of the time of transmission, the direction of transmission and the distance from this country. The five zones decided on were as follows :—

Zone 1 : Australia and New Zealand, and the Pacific Islands.

Zone 2 : India, Burma and the Malay States.

Zone 3 : Iraq, Egypt, East Africa and South Africa.

Zone 4 : West Africa, including Nigeria and the Gold Coast, and the Atlantic Islands (Tristan da Cunha and the Falkland Islands).

Zone 5 : Canada, West Indies, Trinidad, British Guiana and the Pacific Islands.

Beam Transmission to be Used

These zones do not subtend the same angle at this country, and arrangements are therefore to be made for the angle of the transmitted beam to be different for each case. Making use of the practical experience of short-wave transmission which has been gathered in past years, the allocation of the eight wavelengths to the five zones was initially decided on as follows :—

Zone 1 will require only one wavelength, since the only waveband likely to be of use is that in the neighbourhood of 25 metres, and thus only one aerial is required for this zone.

Zone 2 will require three wavelengths and three aerials, one each in the 17, 25 and 32 metres bands.

Zone 3 will have two wavelengths and two aerials, viz., 14 and 32 metres, the former wavelength being for use when daylight exists over the whole route.

Zone 4 will have two wavelengths and two aerials, viz., 32 and 48 metres, but the latter of these aerials will be arranged to cover both Zone 4 and the nearer parts of Zone 3.

Zone 5 will require three wavelengths and three aerials, viz., 19, 32 and 48 metres respectively, the last-named being intended to cover Canada only.

It will be noted that certain wavelengths, viz. 25 and 32 metres, are common to more than one zone, and as in some cases the time difference between the two zones in question may not be great, it may be found necessary to transmit to two such zones at the same time. In practice, it is not possible to use exactly the same wavelength for each transmitter, and thus it becomes necessary to have two wavelengths in the 25 and 32 metre bands.

In addition to the eleven directional aerials, six omni-directional aerials (one for each waveband) will be erected to provide for special transmissions at times outside 6 p.m. to midnight local time.

Why Two Transmitters should Suffice

Having decided on the wavelengths and the aerial system to be used, the next question of importance was that of the type and number of transmitters necessary to feed the aerials. If it were necessary to transmit to the five zones simultaneously, it would obviously be necessary to have five separate transmitters, but the time difference between the various parts of the Empire renders it unlikely that we shall have to transmit to more than two zones at one and the same time, but should a contingency arise the omni-directional aerials can be used. It therefore follows that two transmitters will suffice. If at any time in the future the hours of transmission were considerably extended, and if for any reason it became necessary to serve more than two zones simultaneously, then, of course, additional transmitters would have to be added.

The aerial power of the transmitters will be from 15 to 20 kilowatts, and the technical characteristics of the transmitters will be entirely representative of modern broadcasting technique.

WHY A SET SHOULD BE SWITCHED OFF WHEN ALTERING GRID BIAS

THE effective life of a power valve can be considerably shortened by failing to switch off the set when making adjustments to the grid bias voltage. Although on the face of it, it may seem that the operation of changing the grid bias from, say, 7·5 to 9 volts can be accomplished in such a short time that it is unnecessary to switch off the set, there is a definite reason why the set should be switched off. It is not the actual alteration in the value of the grid bias while the set is working that does the damage, but the fact that while the alteration is being made there is for a few moments no grid bias at all on the power valve. This results in a large increase in the plate current, an increase that is far greater than the valve is designed to withstand, and consequently damage is done to the filament.

Incidentally, the effect of grid bias is always to reduce the plate current and changes of a volt or two in grid bias will cause changes in the anode current of several milliamps. The higher the bias, the lower the current.

SIMPLE MODERN RADIO CABINETS

By C. H. HAYWARD

ANYONE who has followed the development of wireless during the last few years must have noticed some striking changes. Changes, not only in the general efficiency of components and sets as a whole, but also in general compactness and convenience of manipulation. The modern set takes up scarcely half the space of its forerunner of a year or two back, and its controls have been reduced to a minimum.

Naturally enough, this has had its effect on the design of cabinets. Instead of a large cabinet filled with bulky pieces of apparatus (and often with coils starting in unexpected places), we have a compact job which sometimes only betrays the fact that it is a wireless set by the presence of a single small control knob. Few sets of to-day show more than a very small amount of panel, and this automatically gives the designer wider scope.

All-in Cabinet

Then again, the majority of people nowadays prefer what is usually called the "all-in" cabinet. It contains everything required for the whole instrument, so that the unsightly appearance of loose wires is eliminated. It is in a large measure owing to the smallness of modern components, and the popularity of the cone speaker instead of the older trumpet type, that this form of cabinet has become practicable.

Modern design in furniture also plays a part in cabinets. The present vogue of wide, unbroken surfaces is reflected everywhere. The decline of overhanging tops and projecting mouldings, too, is seen in wireless woodwork. What, perhaps, has played the greatest part is the ever-growing use of plywood and other manufactured materials, and the general standardisation of furniture parts. The main feature of plywood is the great width in which it can be obtained, and its freedom from shrinkage. In many cases it renders the old construction system of framed-up panelling unnecessary.

TABLE RADIO CABINET NO. 1

This cabinet will accommodate a two- or three-valve set. The controls project through the small fretted shape cut in the main panel. The size and form of the fret can be easily adapted to suit the particular components used. Only the smallest of panels is required, since it has merely to cover the opening. If the large exposed panel is preferred, the wood panel, with its fret, could be omitted

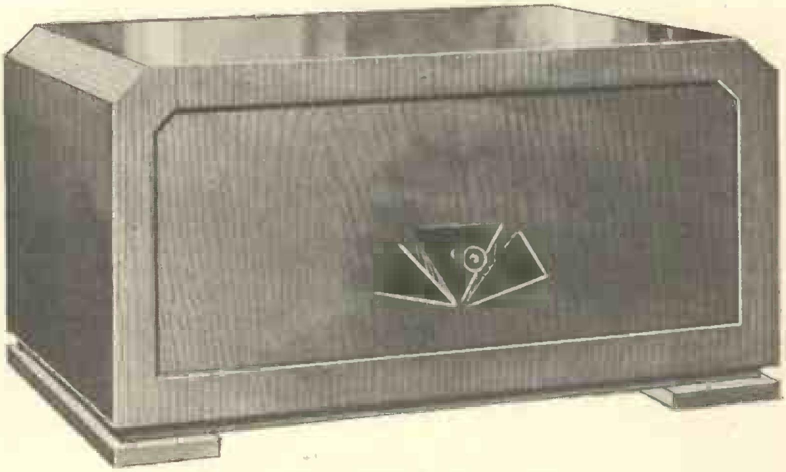


Fig. 1.—THE TABLE RADIO CABINET.
This is suitable for a normal sized two- or three-valve set.

entirely, the ebonite panel fitting immediately behind the main front.

The Canted Corners

The canted corners are effective, and are easily formed by the use of a double rebated moulding which can be seen in Fig. 2. This can be obtained ready made. Its rebates are of a depth suitable to take the standard $\frac{3}{16}$-inch plywood. Its use obviates the necessity of cutting special joints, since the plywood sides and top have merely to be glued and nailed in the rebates.

Fig. 2.—How the Top and Sides of Table Cabinet fit in Rebates of Rebated Corner Moulding.

Cutting the Plywood

As a preliminary step, it is advisable to obtain the moulding so that the exact size can be measured. It enables the length of the top to be calculated—also the bottom which is contained between the sides. The plywood must be cut square, and the edges should be trimmed with the plane to make them clean. It will be found convenient to fix each side to its moulding first, and then add the top. Fig. 2 shows the top being placed in its rebate. Glue should be used in every case, and the nails must be punched in and the holes filled either with wax or plastic wood.

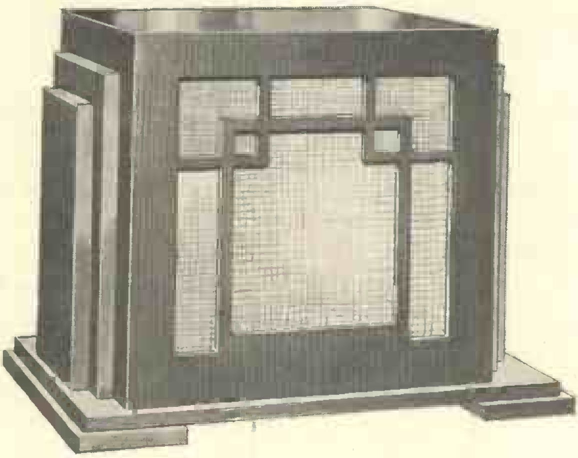


Fig. 3.—The Loud Speaker Cabinet.

Many people prefer to have the loud speaker cabinet separate from the set.

Fixing the Front

After the bottom has been nailed in, the front can be cut out and fixed. Best results are obtained by allowing it a trifle full all round, and levelling after fixing. The inner space can be cut with the fretsaw. The fretted wood panel is fixed with small screws behind the outer front.

To produce the recessed moulding effect, a second bottom is screwed on beneath that already fixed. It should stand in the same distance at front and sides. Below this, again, two battens running from front to back are fixed to form the feet. They line up with the main surface of the sides. It is necessary to provide a rebate in which the back can fit. This is done by fixing small strips of wood near the back edges of the top and sides. No strips are needed for the bottom, since the latter is narrower than the sides, the back fitting behind it as given in the elevation on the chart. Small clips or turns can be screwed on to enable the back to be removed easily when the set has to be withdrawn.

Fig. 4.—The All-in Table Model.
All the components are compactly housed together.

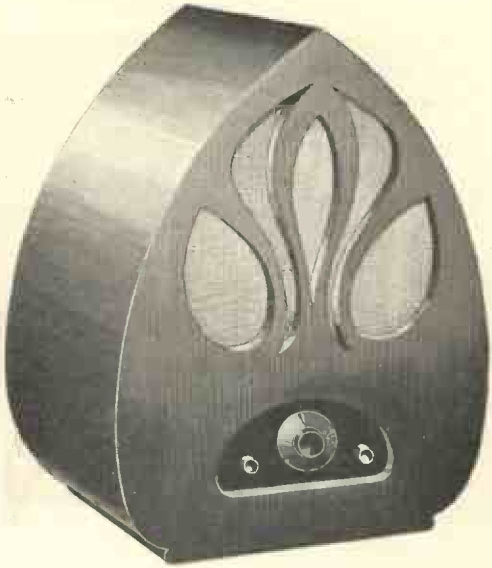


Fig. 5.—Combined Loud Speaker and Radio Cabinet.
A pleasing design for a shaped cabinet.

CABINET FOR SEPARATE LOUD SPEAKER

The separate loud speaker cabinet is still popular. It has the advantage of simplicity. That given in Fig. 3 contains an 11-inch baffle board, and is suitable for the 10-inch or smaller cone. Those using a larger cone or a cone with a large chassis can enlarge the job accordingly. A separate baffle board is the usual thing nowadays, and, apart from the better results it gives, has the advantage in the present instance of enabling the fret to be of a square shape.

Plywood is used for the top and front, but thicker solid wood is advisable for the sides and bottom, as it not only stiffens the whole, but provides a good thickness into which nails can be driven easily. The stepped sides are an essentially modern touch, and are formed by the planting on of pieces of solid wood ½ inch thick.

The Main Cabinet

The main cabinet is in the form of a box. The bottom is contained between the sides, but the top lies over the last named. It is consequently correspondingly longer than the bottom. Another point to note is that the latter is narrower than the sides and top because the back fits behind it. Nail the four pieces together with all the front edges flush, and trim the joints. Glue, of course, is used. The fret should not create any difficulty, as it consists of straight lines only. The design can be drawn in with pencil and rule and cut with the fretsaw. Alternatively, it can be cut locally by a woodworker having a jigsaw. Yet another plan is to obtain a ready-cut fret. The exact design is not important, though one with straight lines would be more in keeping with the general design. Its over-all size should be a trifle more than that of the cabinet, to enable the edges to be trimmed down after fixing. Glue and nails are used to fix it.

Clean Up the Edges

It is worth taking a little extra trouble in cleaning up the edges of the side " step " pieces. Any roughness shows up badly. They should also be perfectly flat to enable close joints to be made. To avoid nail holes at the outside, the two pieces should be fixed together first, driving nails through the larger inner piece into the other. The whole thing is then fixed with nails driven from inside the cabinet.

Glue is essential, as otherwise the pieces may curl away in time.

A lower bottom sufficiently long to project beyond the "steps" is screwed on underneath. Below this are two battens fixed at the sides. To provide a bearing for the baffle board, strips are glued round in the corners behind the fret. The baffle is screwed to these. This detail is shown in the elevation in the chart. Similar strips are fixed near the back edges to form a rebate in which the back can fit. Those readers using a cone without a chassis will have to provide a cross-batten to which the unit can be screwed. This can be a firm fit between the sides, and can be held by small glue blocks rubbed in at the angles.

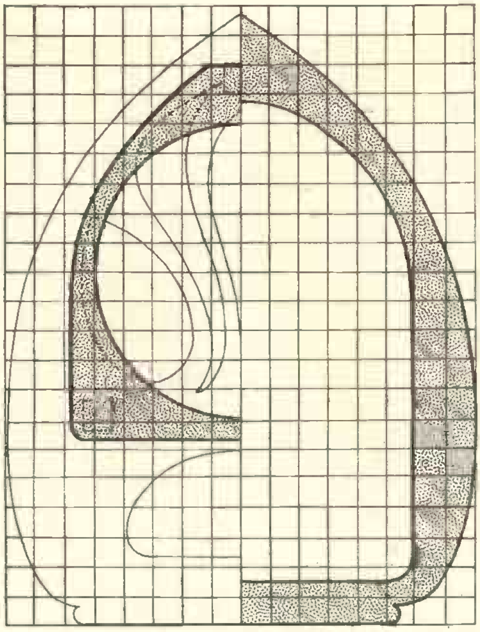


Fig. 6.—Shapes of Baffle Board (left) and Back (right) set out in 1-in. Squares.

ALL-IN TABLE MODEL

Amongst the table models, this form of cabinet in many ways offers the most advantages. All the components are compactly housed together, and the appearance is certainly neater than that of two separate cabinets. The small space into which components can now be built makes the sizes of that in Fig. 4 ample for most sets. There is no difficulty about increasing them if necessary.

Wood to Use

It is desirable to use $\frac{3}{8}$-inch solid wood for the front, partly because it is an essential part of the construction, and partly because the edges show at the sides. The sides, too, are solid $\frac{3}{8}$-inch stuff. For the curved top, $\frac{1}{16}$-inch plywood, bent to shape, is used. The grain of this runs from back to front. It is fixed down over the top edges. Notice from the chart that a top rail is fixed at the back. Its top edge corresponds with that of the front. The side pieces certainly add to the appearance, though they can be omitted if desired. They are pieces of $\frac{7}{8}$-inch solid wood, planed down to a thin edge at the bottom.

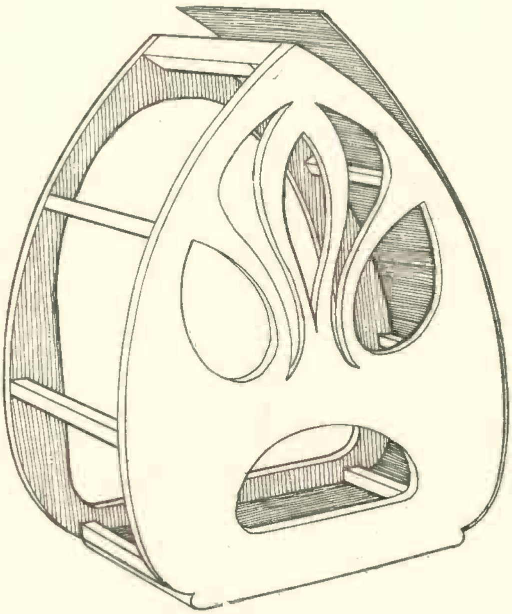


Fig. 7.—Construction Details of Table Cabinet.

The First Step in Construction

The first step is to make the fretted front. Mark out the fret and control opening and cut with the fretsaw. The top curve can be drawn in by cutting a strip of wood about 15 inches long, and driving a nail through it near one end. This nail is driven into the front in the centre measuring from side to side, and at a distance from the top to bring the free end of the strip level with the top of the front.

Tracing the Shape

After cutting out, the back top rail is placed under it and the shape traced round with a pencil. It is important that the two curves are identical. It will be noticed that the rail is fixed *between* the sides, whereas the front passes over them. This means that the rail is shorter by the combined thickness of the two sides. It is fixed to the sides with glue and nails, the sides standing up a trifle at the top so that they can be afterwards planed to the correct slope. The bottom projects slightly at front and sides, and is also glued and nailed.

When fixing the thin plywood top, start at one side, driving in a few nails, and work gradually across. There should be a slight overlap, which can be levelled after the glue has set.

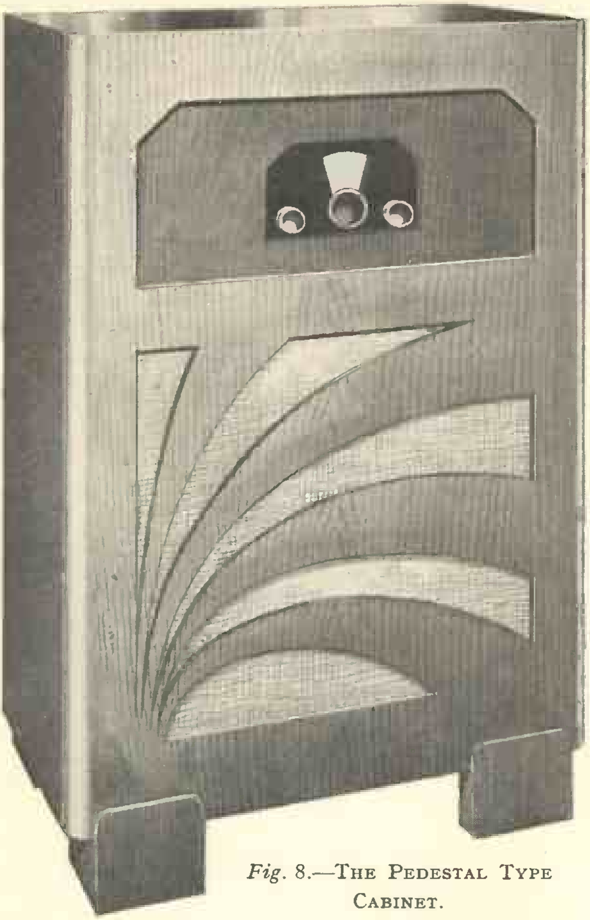


Fig. 8.—The Pedestal Type Cabinet.

The Double Bottom

There is no need to use a solid piece to form the double bottom. Narrow pieces can be mitred round as given on the chart. Take care when making the tapered side pieces to keep the corresponding members the same length.

Fillets are glued behind the front to enable the baffle board to be fixed. The simplest way of dealing with the back is to screw it straight to the back edges, or to provide clips to hold it.

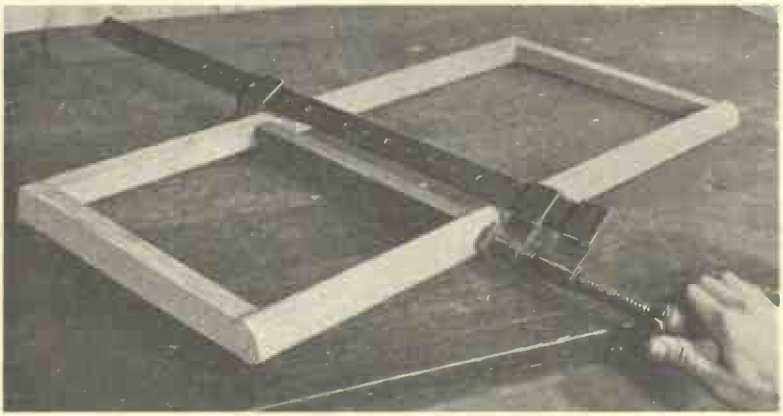


Fig. 9.—Cramping Up One Side.
This is the first stage in assembling the framework of the cabinet.

SHAPED TABLE MODEL

Shaped cabinets are popular at the present time. They have become economically possible owing to the use of plywood, which can be bent easily to shape, thus saving what would be an expensive form of construction if carried out in solid wood. That in Fig. 5 consists virtually of a fretted front and back joined together with struts and a bottom, and with thin plywood bent round to form the sides.

Plotting Out the Shape

Fairly thick plywood should be used for front and back, as the nails holding the bent sides have to be driven into the edges. The marking out of the shape can be followed easily from the diagram in the chart. The squares shown represent 1 inch each, and if a corresponding series of squares is drawn full size on the plywood or on a sheet of paper, the shape can be plotted out as if it were a map. A good plan is to plot in one-half of the design on paper, fold the latter along the centre, and trace the pattern through to the other half. In this way perfect balance is ensured.

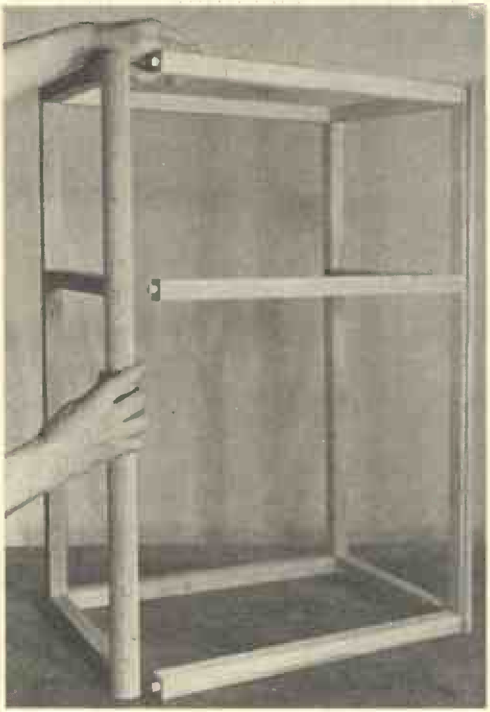


Fig. 10.—Assembling the Main Framework. Notice that the rails are flush with the rebates of the front uprights.

Cutting Out Front and Back

The outer line of the back corresponds with that of the front, but, in place of the fret, a large opening is cut. This is shown to the right in Fig. 6. When cutting the back, special care should be taken to keep carefully to the line, because the piece cut away is used to act as a door. A fretsaw can be used to cut the frets, but a simpler plan is to have them cut on a jigsaw. When front and back have been cut they should be placed together in the vice, and the edges trued with a spokeshave, or with coarse glasspaper wrapped around a flat block. This ensures both being alike in shape.

Baffle Board

A baffle board is required to fix behind the front. Its shape is given to the left in Fig. 6. Plywood $\frac{3}{8}$-inch thick is used. The dotted lines in the corners show the positions of the blocks by which it is joined to the front. Screws are driven into the blocks and front. It is advisable to fix the baffle at this stage. A piece of tinsel fabric is first glued at the back of the fret.

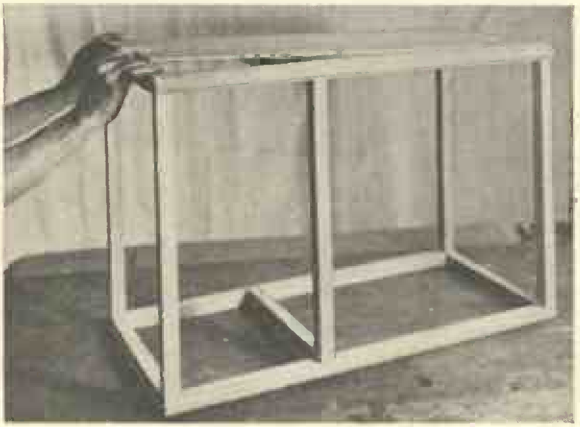


Fig. 11.—This shows a Side being Laid In.

Joining Front and Back Together

To join the front and back together, the bottom and seven struts are used. The length of the last-named equals the width of the bottom. Fig. 7 shows the struts fixed. Glue and nails are used, the last-named being punched in and the holes filled. They should project slightly beyond the edges so that they can be levelled afterwards. This applies especially to the top strut, the square edges of which must be made to accord with the curve of the front and back.

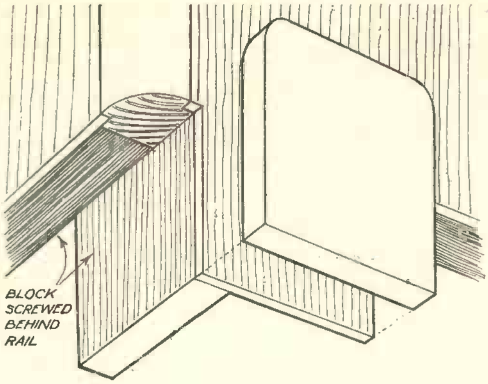


Fig. 12.—Close-up View of Foot of Pedestal Model.

For the front uprights a double rebated moulding is used, the rebate being of the correct depth to take the plywood. It is a standard pattern, and can be obtained ready made if desired. Plain square pieces are used for the back uprights and rails. The only exceptions are the middle side rails, which are wider and lie flat to form a support for the baseboard.

The various sets of rails can be fixed together and marked off and cut all to the same length. The same thing applies to the uprights when the dowel holes are being marked out. A gauge can be used to mark the distance in from the edges.

Put the two sides together independently first. Fig. 9 shows one being assembled. A cramp is certainly an advantage to ensure close joints. When the glue has hardened, the front and back rails can be added, as in Fig. 10. Notice that the rails are flush with the rebates of the front uprights.

The Sides

For the sides, thin plywood with the grain running crosswise is used. If there is any difficulty in making it bend around the rather acute curve at the bottom, it can be first soaked in warm water, or it can be steamed. Start at the bottom, and work gradually towards the top, driving in the nails and glueing as the work proceeds. The edges should overhang slightly to allow for trimming afterwards. After levelling the top edge of the one side, the other is fixed in a similar way.

The back is easily hinged, there being a straight part in the general shaping specially for the purpose.

PEDESTAL MODEL CABINET

A cabinet of this type (Fig. 8) can be made up cheaply. It consists chiefly of a light framework dowelled together with the various panels of plywood fixed with glue and nails.

Fig. 13.—The Radio Gramophone Cabinet.

In this cabinet the three advantages of economy, simplicity and an attractive appearance are combined. The cabinet is plenty large enough for most purposes.

Fixing the Sides and Front with Glue and Nails

The next stage is that of fixing the sides and front. Fig. 11 shows a side being laid in.

Glue can be used, as there is no danger of plywood shrinking and so splitting. Drive in nails at intervals of 3 or 4 inches. The front must be fitted carefully, as it has to fit exactly in the

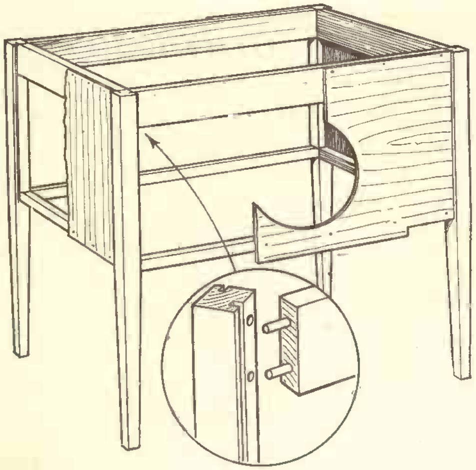


Fig. 14.—View showing Main Construction of Radio Gramophone.

rebates. The fret should preferably be cut on a jigsaw. Notice that it projects downwards at the bottom to form the feet. This is shown clearly in Fig. 12. This illustration also shows how blocks are screwed to the side rails behind the feet, and how the front feet pieces are glued on. The back feet are formed by pieces screwed to the rails.

Allow the top to project slightly all round so that it can be afterwards levelled. The corners of the bottom must be cut to fit around the corner uprights.

RADIO GRAMOPHONE

Chief construction details of this model are given on the chart, but a study of Fig. 14 will prove useful. The main structure of legs and rails is shown clearly. Also the fitting of the panels in their grooves. As in all similar jobs, it is an advantage to put the sides together first and allow the glue to set before adding the front and back rails.

Fig. 15 shows the lid construction. The moulding can be obtained ready made. It is mitred at the corners. The opposite pieces must be exactly the same length. It is an advantage to put the parts together in the form of two letters L, and join these afterwards. If desired, a flat strut can be fixed beneath the top in the centre to stiffen it.

The Radio Cabinet Chart

In the designs given in our chart, we have selected types which cover the requirements of the up-to-date set. The sizes given will be found to be suitable for most sets, but there is no need to follow them slavishly. It is simple to adapt them and to alter the cutting list accordingly. The materials suggested are more or less standardised, and can be obtained from woodworkers' suppliers. Such parts as mouldings can be purchased ready made, a section nearest to that given being selected.

For those who prefer to house the loud speaker separately, there are single cabinets. In addition there is the all-in type both for the table and to stand on the floor. The other type is the radio-gramophone, which is becoming increasingly popular. There are obvious advantages in keeping both wireless and gramophone in one cabinet, since, apart from its convenience, it enables the gramophone to be fitted with a pick-up and play through the cone.

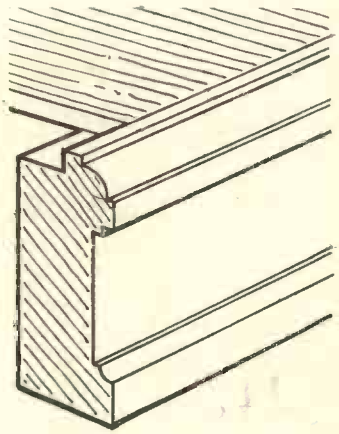


Fig. 15.—Detail of Lid of Radio Gramophone.

NEWNES' RADIO CABINET CHART

This Chart, which has been specially prepared for Newnes' "Complete Wireless" by Mr. C. H. Hayward, contains details relating to six different designs. The particulars given will enable readers either to construct the Cabinets or to obtain close estimates for quantities on a production basis.

CUTTING LISTS

An extra allowance has been made in length and width to allow for trimming

Table Radio Cabinet, No. 1.

Front	1 piece	10⅛″ × 19¼″ × 3/16″ plywood.
Panel	1 ,,	9″ × 18½″ × 3/16″ ,,
Back	1 ,,	19″ × 10″ × 3/16″ ,,
Top	1 ,,	17″ × 11″ × 3/16″ ,,
Sides	1 ,,	9¼″ × 11″ × 3/16″ ,,
Bottom	1 ,,	19″ × 10¾″ × ⅜″ satin walnut.
,,	1 ,,	18¾″ × 10½″ × ½″ ,,
,,	2 pieces	11¼″ × 3⅛″ × ½″ ,,
Corners	2 ,,	rebated moulding, 11¼″ × 1⅛″ square.
Fillets	2 ,,	10″ × ⅜″ × ⅜″ satin walnut.
,,	1 piece	19″ × ″⅜ × ⅜″ ,,

Loud Speaker, No. 2

Fret	1 piece	12¼″ × 12¼″ × 3/16″ plywood.
Top	1 ,,	12¼″ × 7″ × 3/16″ ,,
Sides	2 pieces	12″ × 7″ × ½″ satin walnut.
Side Pieces	2 ,,	10¾″ × 6″ × ½″ ,,
,,	2 ,,	9¼″ × 5″ × ½″ ,,
Bottom	1 piece	11¼″ × 7″ × ½″ ,,
,,	1 ,,	15″ × 7½″ × ½″ ,,
,,	2 pieces	8″ × 3⅝″ × ½″ ,,
Back	1 piece	12″ × 12″ × 3/16″ plywood.
Baffle	1 ,,	11½″ × 11½″ × ⅜″ ,,
Fillets	7 pieces	12″ × ⅜″ × ⅜″ satin walnut.

All-In Table Model, No. 3

Fret	1 piece	19¼″ × 13⅛″ × ⅜″ satin walnut
Sides	2 pieces	18″ × 9¾″ × ⅜″ ,,
Top	1 piece	10¼″ × 15″ × 1/16″ plywood.
Bottom	1 ,,	14″ × 10½″ × ½″ satin walnut
,,	2 pieces	15″ × 2″ × ½″ ,,
,,	2 ,,	11½″ × 2″ × ½″ ,,
Side Pieces	2 ,,	16″ × 9¼″ × ⅞″ ,,
,,	2 ,,	14″ × 8¼″ × ⅞″ ,,
Back	1 piece	18½″ × 13″ × 3/16″ plywood.
Baffle	1 ,,	12″ × 12″ × ⅜″ ,,
Fillets	4 pieces	12″ × ¾″ × ⅜″ satin walnut.
Back Piece	1 piece	13″ × 2½″ × ½″ ,,

Combined Loud Speaker and Radio Cabinet, No. 4

Fret	1 piece	21″ × 16½″ × ⅜″ plywood.
Back	1 ,,	21″ × 16½″ × ⅜″ ,,
Baffle	1 ,,	13½″ × 12″ × ⅜″ ,,
Bottom	1 ,,	12″ × 9½″ × ⅞″ satin walnut.
Fillets	6 pieces	10½″ × ¾″ × ¾″ ,,
,,	1 piece	10½″ × 1¼″ × 1¼″ ,,
Blocks	3 pieces	1″ × 1″ × ⅜″ ,,
Sides		10½″ × 26″ × 1/16″ plywood.

Pedestal Type Cabinet, No. 5

Uprights	2 pieces	rebated moulding, 1¼″ sq. 30½″.
,,	2 ,,	30½″ × 1″ × 1″ satin walnut.
Rails	5 ,,	18″ × 1″ × 1″ ,,
,,	4 ,,	12½″ × 1″ × 1″ ,,
,,	2 ,,	12½″ × 1½″ × 1″ ,,
Front	1 piece	33½″ × 18½″ × 3/16″ plywood.
Panel Piece	1 ,,	8″ × 18″ × 3/16″ ,,
Sides	2 pieces	30½″ × 13½″ × 3/16″ ,,
Top	1 piece	20½″ × 14¼″ × 3/16″ ,,
Back	1 ,,	30″ × 20″ × 3/16″ ,,
Baffle	1 ,,	19″ × 19″ × ⅜″ ,,
Bottom	1 ,,	20″ × 14″ × 3/16″ ,,
Feet	2 pieces	4⅛″ × 4⅛″ × ¼″ satin walnut.
,,	6 ,,	4⅛″ × 4⅛″ × ½″ ,,

Radio-Gramophone Cabinet, No. 6

Legs	4 pieces	30″ × 1⅜″ × 1⅜″ satin walnut
Rails	2 ,,	28″ × 3⅛″ × ⅞″ ,,
,,	2 ,,	28″ × ⅞″ × ⅞″ ,,
,,	2 ,,	16″ × 3⅛″ × ⅞″ ,,
,,	2 ,,	16″ × ⅞″ × ⅞″ ,,
Front	1 piece	28″ × 16¼″ × 3/16″ plywood.
Sides	2 pieces	15¼″ × 16″ × 3/16″ ,,
Back	1 piece	28″ × 15¼″ × 3/16″ ,,
Motor Board	1	27½″ × 15¾″ × ⅜″ ,, (can be in two pieces)
Bottom	1 piece	30″ × 18″ × 3/16″ ,,
Top	1 ,,	30″ × 18″ × 3/16″ ,,
,,	2 pieces	moulding 31½″ × 2½″ × ⅞″.
,,	2 ,,	,, 19½″ × 2½″ × ⅞″.
Fillets	2 ,,	18″ × 1½″ × ½″ satin walnut.
,,	2 ,,	11″ × ½″ × ½″ ,,
Hinge Piece	1 piece	28″ × 1″ × ½″ ,,
Fret and Rim Moulding	2 pieces	16½″ × ⅞″ × ¼″.

Satin Walnut and Plywood are specified throughout. Any hardwood and inured plywood can be substituted if desired

INEXPENSIVE RADIO-GRAMOPHONE

Takes 12 in. or larger Records
For horizontal Panel

In this cabinet the three advantages of economy, simplicity, and an attractive appearance are combined. It is plenty large enough for most purposes. The gramophone motor, turntable, and so on are to the right. To the left is the space for the set. It is intended that the panel should be horizontal, the controls passing through holes made in the continuation of the motor board to the left. If desired, the motor board could be in two separate pieces, so that the one could be moved without interfering with the other. The cone is central, and fits behind a circular hole cut in the front. A separate fret and rim are fitted to the hole.

For the lid it is advisable to use ready made moulding, as it is a rather difficult section to work. Many patterns are available. It is usually provided with a rebate at the top to hold the plywood top. The advantage of the deep moulding is that it allows plenty of depth for the tone arm and other components. If a thick baffle board is considered necessary, this could be screwed to battens fixed to the back of the front panel.

Light Cabinet, economical yet attractive

CABINET, No. 6

Simplicity of construction is ensured by the use of grooved legs to which a series of rails forming the main framework are fixed. The rails are joined with dowelled joints, and are arranged so that they are flush with the inner edges of the grooves. This enables the panels to be slid in the grooves and be fixed to the rails with nails. The front legs have two grooves to hold the front and side panels. Those at the back have only one groove each, as the back merely rests against the rails. Fillets are fixed to the legs to form a rebate in which the back can fit. The reason for this is that the latter must be loose to enable adjustments, battery replacements, and so on to be effected.

The front is in one piece. Its bottom edge is shaped, and at the breaks two pieces of moulding are fixed. Many suitable wide, flat sections are available. It will be seen from the semi-sectional view beneath that the motor board rests upon wide fillets fixed *beneath* the top rails. This is advisable as it gives the maximum depth in the space beneath the top.

The legs are tapered and are the standard 30 in. by 1⅜ in. type. If desired, they can be obtained ready grooved. Those who prefer to do all the work themselves can obtain 1⅜-in. squares, work the grooves, and taper the lower part at a distance of 15 in. from the top.

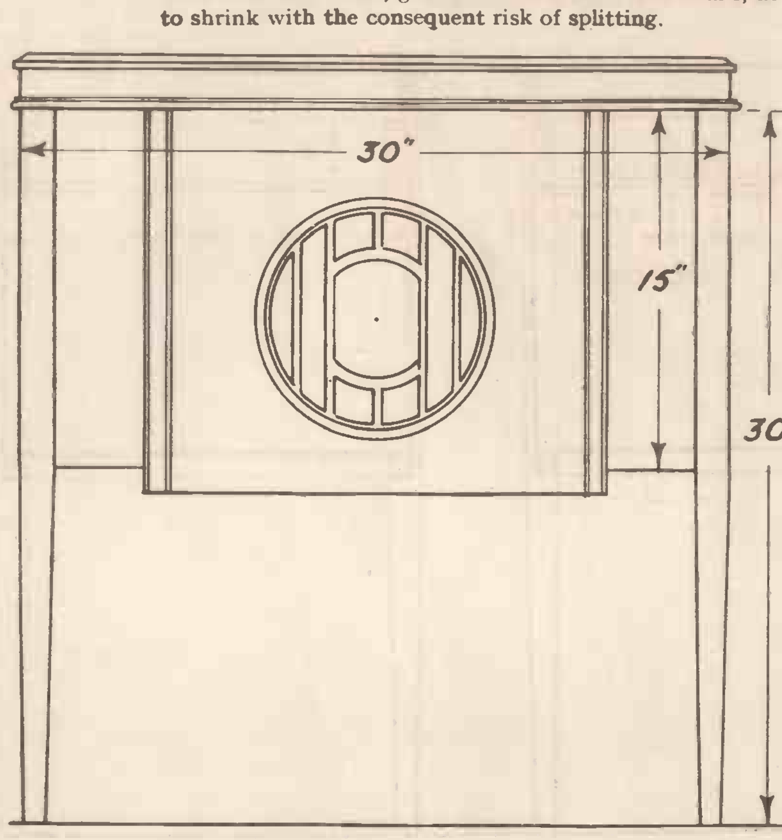
To ensure accuracy in marking out, they should be fixed together temporarily with a cramp and the marks squared across all four. The top rails being 3 in. wide, it is necessary to have two dowels to each joint. The narrower lower rails need only one dowel each.

All the holes having been bored (⅜-in. dowel is the most suitable), the glueing up can be started. Put together the two ends by themselves, and add the front and back rails after the glue has set. The side and front panels can be passed into position from the top afterwards. Note that the front projects downwards in the centre below the rail. As plywood is used for both sides and front, glue can be used as well as nails, as there is no liability to shrink with the consequent risk of splitting.

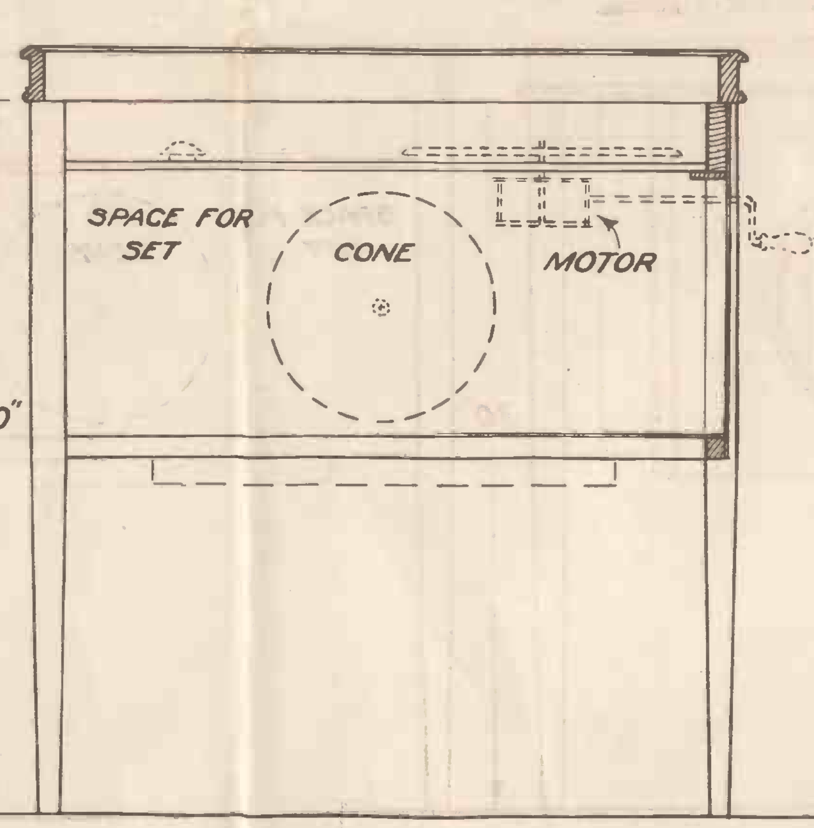
The kind of rim usually fitted is rebated, and, as this rebate has to fit the hole cut in the front, it is advisable to obtain it first so that the exactly correct size can be cut. The fret is fixed at the back. A baffle board can be added if desired.

The lid moulding is mitred at the corners, and the plywood top fits in the rebate. As the top rail of the cabinet is set in from the back of the legs, it is necessary to fix a strip along the rail to make the whole thing flush at the back. Otherwise the hingeing will be awkward. To stiffen the lid in the middle a piece of ½-inch stuff can be fixed to the underside from back to front. A strut is advisable. It will probably be necessary to make a hole in the motor board through which it can pass.

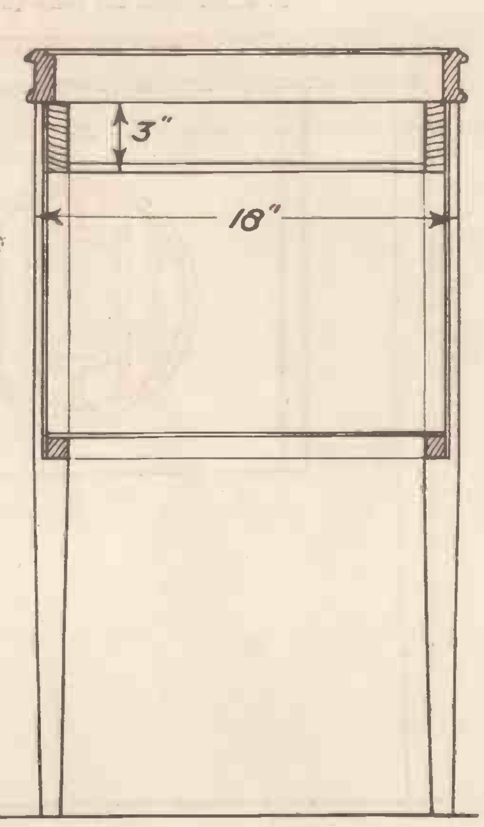
The actual arrangement for housing the set is best decided by the reader. The panel being horizontal, either a sort of open box can be made, or a baseboard can be arranged in a vertical position.



Front Elevation, with Sizes

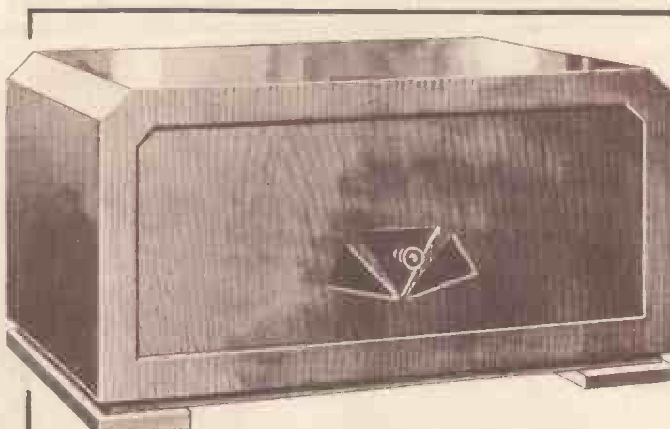


Semi-sectional View showing accommodation



Side Section, with Sizes

WITH PART 14



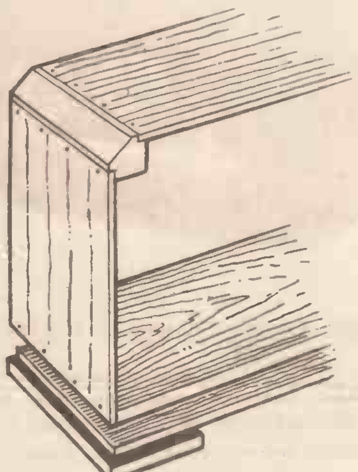
For the Two or Three Valve Set

TABLE RADIO CABINET, No. 1

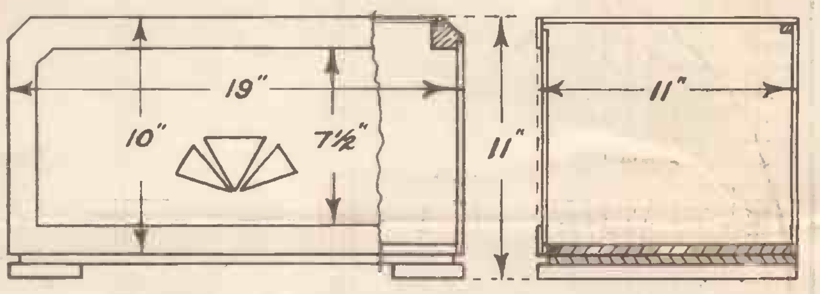
Holds Panel up to 18 in. by 7 in. Baseboard depth, 10 in.

The majority of modern sets have few controls, which renders a large exposed panel unnecessary. In this cabinet a supplementary plywood panel is fitted behind the main front, and this can be pierced to suit any particular arrangement of controls. The sizes given are suitable for the average two or three valve set, though there is no need to follow them rigidly.

The canted corner effect is produced by means of a special rebated moulding which can be obtained ready made. The experimenter can easily rebate and chamfer his own wood if he so prefers. Plywood is used for top and sides, and these fit into the rebates of the moulding. For the bottom, $\frac{3}{8}$-in. stuff is used, and this is contained between the sides. A second bottom is fixed beneath, this being smaller to produce the recessed effect. Two battens fixed at the ends form the feet. The front is cut away inside, and is fixed over the whole. The supplementary panel fits behind it. Fillets are fixed to the sides and top $\frac{3}{16}$ in. from the back edges to form a rebate in which the back can fit.



Construction Detail

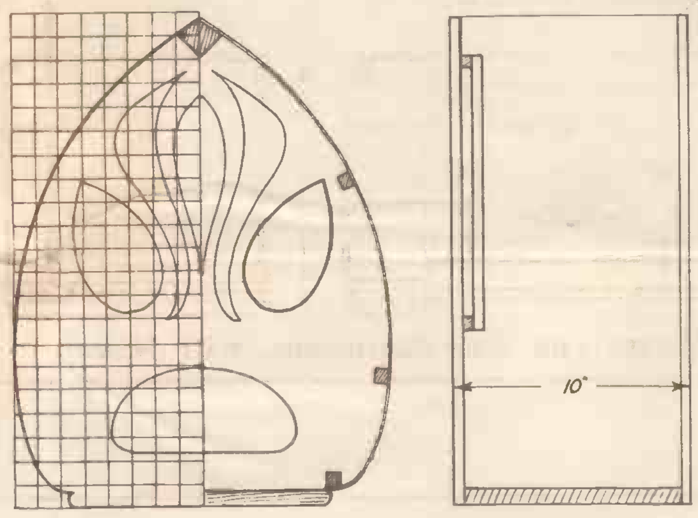


Front and Side Elevations, with Sizes

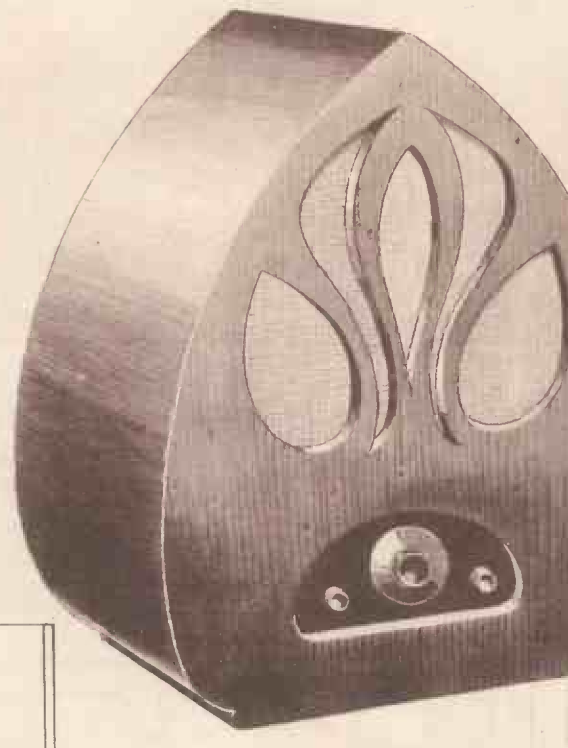
COMBINED LOUD SPEAKER and RADIO CABINET, No. 4

Hold Panel up to $11\frac{1}{2}$ in. by $5\frac{1}{2}$ in. Baseboard depth, $8\frac{1}{2}$ in.

For the front and back $\frac{3}{8}$-in. stuff is used. These are joined by the bottom and a series of struts. After fixing, they are levelled down to the curve of the front and back, and $\frac{1}{16}$ in. or $\frac{1}{32}$ in. plywood bent round. The grain of this must run crosswise. Start at the bottom and work gradually round to the top, glueing and nailing as the work proceeds. The top edge is then trimmed, and the remaining side added in the same way. The edges should overhang at front and back. They are levelled after the glue has set.



Shape set out in 1 in. Squares and Side Section

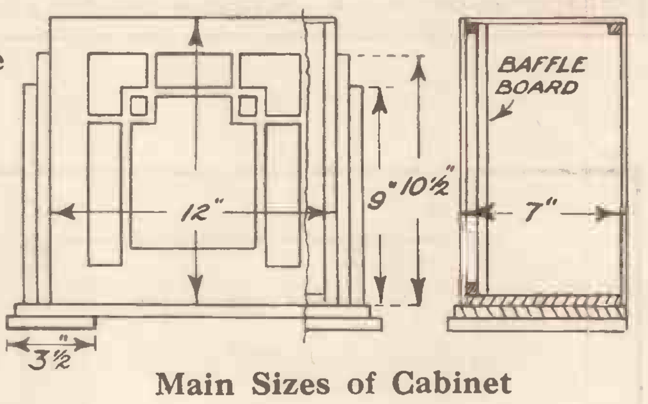


Easily made shaped Cabinet

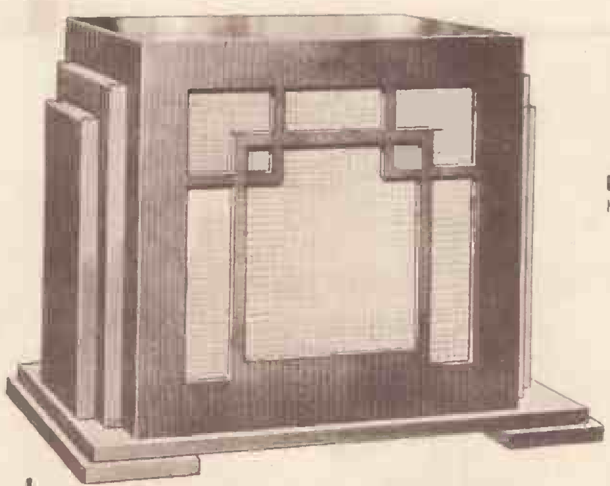
A baffle board is necessary, and this should be fixed to the back of the front with three blocks before the struts are nailed on. The back is pierced with a hole sufficiently large for the cone and baseboard to be inserted. The piece cut away should be retained so that it can be used afterwards as a door. This necessitates the sawing being done carefully.

LOUD SPEAKER, No. 2

Takes Baffle Board, 11 in. square Interior depth, $5\frac{1}{2}$ in.



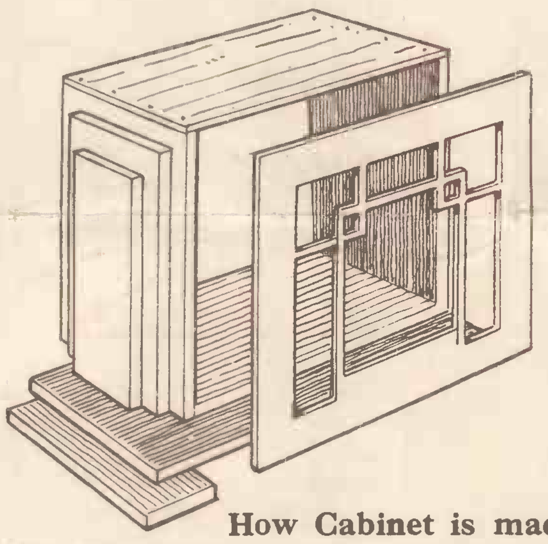
Main Sizes of Cabinet



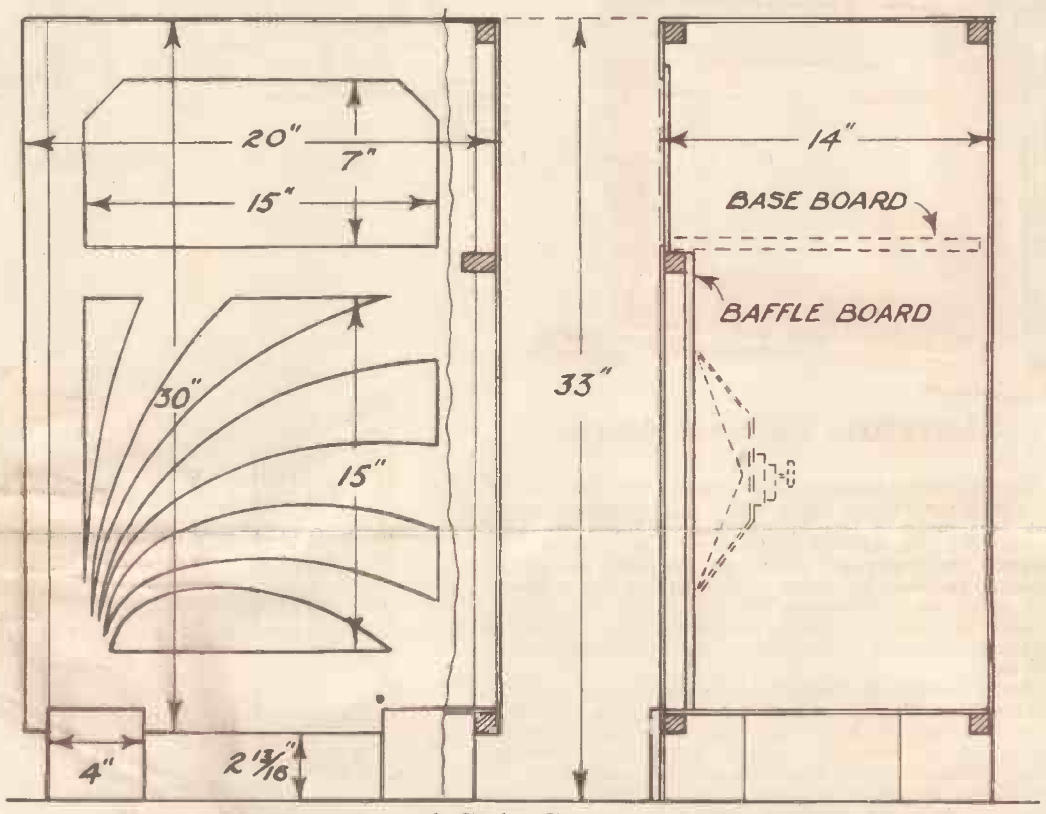
Attractive Compact Model

This cabinet is intended to have a separate baffle board, to which the cone is fitted. This allows the fret to be cut to a more or less square shape. Fillets are fixed behind the fret, and the baffle is screwed to these. To produce the "stepped" effect at the sides, pieces are glued to the sides as shown. Two bottoms are required. The upper one fits between the sides, whilst the other is screwed on beneath, and is sufficiently large to project at front and sides. Two battens fixed underneath form the feet.

When assembling, the sides are first glued and nailed to the bottom. The top, which lies on the sides, is fixed next. After levelling the front edges the fret is fixed over the whole. The "stepping" pieces follow, and then the under-bottom. Tinsel fabric should be glued behind the fret before the addition of the baffle. Fillets fixed near the back edges form rebates for the back.



How Cabinet is made



Front Elevation and Side Section, with Main Sizes

PEDESTAL TYPE CABINET, No. 5

For Panel up to 18 in. by 8 in. Baseboard depth, 13 in.

A light framework to which the front, sides, and top can be fixed is made up first. It consists of two front uprights formed from rebated moulding, two back uprights made of 1-in. square stuff, and a series of rails mostly of 1-in. square stuff also. The only exceptions are the middle side rails, which are $1\frac{1}{2}$ in. wide. They project inwards to form a support for the baseboard of the set. The whole thing is dowelled together. The rails are flush with the rebate of the moulding at the front. This enables the front and sides to be glued and nailed down flush.

The front projects downwards to the floor, the shape of the square feet being cut at the bottom. After fixing, $\frac{1}{4}$-in. blocks are glued over the feet portions as shown. To strengthen them at the back and to form the return at the sides, other blocks are screwed to the inner surfaces of the bottom rails. The sides reach down to the bottom only. The back feet are separate and are screwed to the rails. After levelling the top edges, the top is glued and nailed down. It should overhang a trifle to allow of cleaning up afterwards.

The rebated front uprights and the square pieces at the back are the same length. It is advisable to fix them all together when marking out the positions of the rails, and square the marks across all four. A single dowel is sufficient at each joint. When assembling, the side frames should be put together independently and the glue allowed to harden. Front and back rails can be added afterwards. The advantage of this is that the two ends can then be treated as complete units, and the necessity of dealing with many joints in one operation is avoided.

The front is of plywood. The fret and panel opening can be marked out partly with rule and square, and partly free-hand. It will probably be impossible to use the fretsaw owing to the limited length of the frame of the latter. A keyhole saw must be substituted—or, better still, it can be cut locally at a shop where a jig-saw is installed. The edges must make a nice fit in the rebates of the uprights. When dealing with the sides, the back edges should project $\frac{3}{16}$ in. to form a rebate in which the back can fit. Glue and nails serve to hold the panels to the framework. The nails should be punched in and the holes filled.

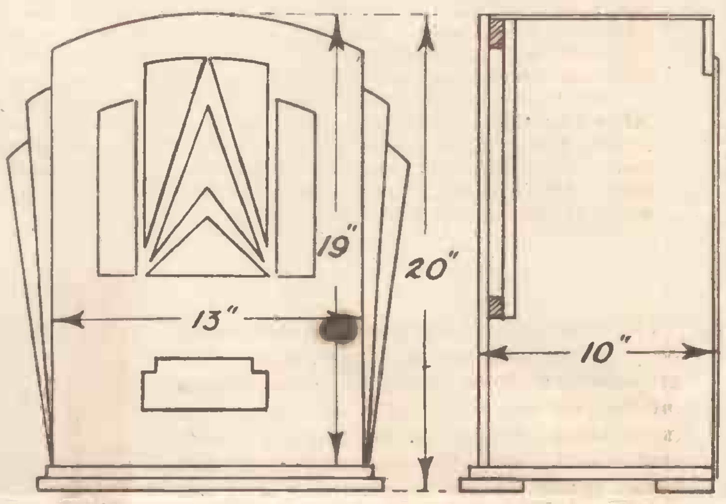
The baffle board is sufficiently wide to enable it to be fixed to the back edges of the front uprights. In the upper part, the large opening is backed by a plywood panel behind which the ebonite panel is fixed. The baseboard is not fixed, but is loose, so that the whole set, including the panel, can be withdrawn. It is long enough to rest upon the horizontal side rails. The back can either be screwed on or be fixed with small turns. The latter arrangement is the better.

Cabinet easily made with Plywood

THE ALL-IN TABLE MODEL, No. 3

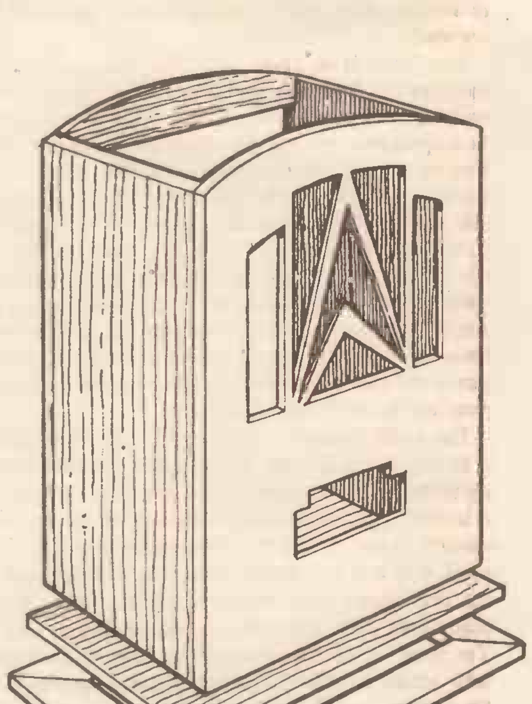
For Panel up to 12 in. by 6 in. Baffle Board, 12 in. square

Here the fret is $\frac{3}{8}$ in. thick. The sides are fixed behind it. A top back piece, cut to a shape to correspond with that of the front, is fixed as shown. The bottom projects all round, and is screwed or nailed on. Beneath it a mitred framework is secured. To form the curved top, $\frac{1}{16}$-in. plywood is used. This is easily bent to shape. A baffle board is screwed to fillets glued behind the fret. The flanking side pieces are simply plain $\frac{7}{8}$-in. pieces planed down to about $\frac{1}{16}$ in. or $\frac{1}{8}$ in. at the bottom. Glue and nails serve to hold them. A shelf can be added as desired, but is usually unnecessary.



Over-all Sizes and Elevations

Suitable for the average small set



(RIGHT) Details of Construction

LOCATING FAULTS IN WIRELESS SETS

By J. H. A. WHITEHOUSE

IN a radio school in which the writer was interested a trick was devised to sort out those who had the right idea about "trouble shooting" from those who had not. Newcomers were asked to repair an electric bell, the wires of which passed through a wall into the next room.

It was very rarely that the "guesser" made that bell work in an hour or even two hours due to: (1) taking something for granted; (2) doing a tremendous lot of guessing.

Fig. 1.—REMOVING DUST FROM BETWEEN CONDENSER VANES.
Dust between condenser vanes can be a frequent cause of crackling and other noises. It can be removed with a pipe cleaner as shown.

The Broken Wire

The secret was that one of the wires entering the wall was cut ½ inch inside the plaster.

Nearly every one took the wiring for granted.

A Few Things that the Trouble Shooter should always have

It is not essential for the amateur to have all this equipment, but for a professional Trouble Shooter, or even the man who takes his hobby seriously, it is vital.

(1) A pair of earphones *in good order*.

(2) A pocket lamp cell *in good order*.

(3) Either a spirit or electric soldering iron. (The Tinol or "Rawl Plug" spirit outfit is excellent.)

An ordinary iron nearly always means running backwards and forwards to the kitchen, which is bad for two reasons: the iron is usually half cold before you can use it, apart from the fact that it is a nuisance to all concerned.

(4) A roll of *fresh* insulating tape (*in a tin*, to keep it fresh).

(5) A long thin screwdriver with the whole of the shaft, except the very tip, covered with bicycle valve tubing, or some similar insulating material—most valuable as a test-prod.

(6) A small buzzer mounted on a board for providing a test signal.

(7) An "avo meter," because it is the most comprehensive measuring instrument of its kind, and protected by a fuse. (Don't forget to keep a few spare fuses.)

ENGINEERS . . .

SIT DOWN AND THINK THIS OVER

THIS 200 PAGE BOOK ON SUCCESSFUL ENGINEERING CAREERS FREE

We *believe* that our 200 page Handbook "ENGINEERING OPPORTUNITIES" will show you the way to well-paid, permanent and progressive employment. In any case, the Handbook costs nothing, and it will at least show you various surprising possibilities about which, at present, you probably know nothing. **Can you**, can any man who cares a 'hoot' about his future, afford to allow this opportunity for a worth-while job to pass by unheeded? Think it over. Can you? We want you to read "ENGINEERING OPPORTUNITIES." Among other things it gives details of all recognised Examinations (A.M.Inst.C.E., A.M.I.Mech.E., I.E.E., G.P.O., etc.), outlines modern Home-study Courses in all branches of Civil, Mech., Elec., Motor, Radio, Aero and Talkie Engineering, and explains the unique advantages of our Employment Department. The book is quite free. Send a post-card for your copy NOW. We promise that it will be a moment of your time well spent. The BRITISH INSTITUTE OF ENGINEERING TECHNOLOGY, 391, Shakespeare House, 29-31 Oxford Street, London, W.1.

The Finest

BRITISH Magazine

The

STRAND

MAGAZINE

Obtainable at all Newsagents and Bookstalls **1/-**

BULGIN

The Choice of Critics

OVER 500 COMPONENTS IN THIS FAMOUS RANGE

Incorporated in many leading sets. Specified by the experts.

TRANSFORMERS
TRANSCOUPLERS
RESISTANCES
FUSES
PLUGS
JACKS
METERS
VOLUME-CONTROLS
ETC., ETC.

SEND FOR NEW 80-PAGE Catalogue "D" and Manual. Enclose 2d. postage.

A. F. BULGIN & Co. Ltd. Abbey Rd., Barking
Telephone - - - - Grangewood 3266/7

An Essential Book for the Wireless Amateur

THIS book is written for the amateur who desires a fuller knowledge of his subject. It will enable you to attempt research and experiments which before were far beyond your powers. The author has the gift of explaining abstruse subjects in a simple fashion. Fully Illustrated.

THE MATHEMATICS OF WIRELESS

By RALPH STRANGER

5/-

Obtainable at all Newsagents and Bookstalls, or by post 5s. 3d. from George Newnes Ltd., 8–11 Southampton Street, Strand, London, W.C.2.

Geo. Newnes Ltd.

This article on "Locating Faults in Wireless Sets" is continued in Part 5. Ready October 14th. Order your copy to-day.

HANDICRAFTS 1933 ANNUAL

Do you want a Wireless Cabinet, Radio-Gramophone, or Loud-Speaker?

This book, with its innumerable action photographs and clear diagrams, shows you how you can make it easily and at extraordinarily low cost.

In addition are full particulars of

OVER 40 WIRELESS CABINETS AND LOUD-SPEAKERS

These are all ready to assemble, all joints being cut, and all wood prepared. Furthermore, the prices at which they are offered are little short of startling.

THIS BOOK IS

OF INTENSE INTEREST TO THE RADIO MAN

In addition to the splendid literary section is a *complete illustrated list* of all materials for making and finishing radio cabinets, including over 40 frets and rims, baffle boards of all sizes and thicknesses, moulded tops, legs, rails, panels, mouldings, handles, hinges, gramophone motors, cones, units, tinsel fabric, and so on.

OVER 350 PAGES AND A FREE COPY OF HANDICRAFTS MAGAZINE IS GIVEN WITH EVERY ANNUAL.

A few of the things you will find in Handicrafts 1933 *Annual:*

12-page Course on Amateur Woodwork with real action photographs; Article on making a Radio-Gramophone; Modern Table Cabinet; How to finish your woodwork.

The above are literary articles, and are in addition to the complete list of fittings and materials. Besides these are articles on making all sorts of useful things for the home.

YOU CANNOT AFFORD TO MISS THIS BOOK EVEN FOR ONE DAY!

GET YOUR COPY NOW

Obtainable from any newsagent, or from any of the branches of Messrs. Curry or Messrs. Halford, or from any Handicrafts Agent. Alternatively it will be sent direct for 1s. post free.

1/-

HANDICRAFTS LTD., Weedington Road, Kentish Town, London, N.W.5

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8-11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

THE 7-METRE THREE

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

SERVICING H.M.V. RECEIVERS

1/-

Part 5

IN ABOUT 24 WEEKLY PARTS

(8) A 9-volt grid battery and various plugs and leads.

(9) Two or three valve holders. (Very handy if you strike a broken clip in one of the modern mass-produced jobs where the holders are all in one strip.)

(10) Two or three 2-microfarad mica condensers—useful for "testing by substitution."

(11) A multiple-ratio low-frequency transformer with adjustable taps. (For coupling up high-resistance phones to a low-resistance output, etc.)

(12) A length or two of systoflex.

(13) A lamp holder and 5 and 10 amp. plugs.

(14) A valve adaptor. This has extension leads and can be applied to any valve holder of the 4- or 5-pin type, and will make any measurement possible, either with the valve in position or not, as required.

(15) Fuse wire wound on a card.

(16) A dozen yards or so of rubber-covered single flex wound on a card. (Very useful as a temporary aerial or earth lead to replace a suspect.)

Fig. 2.—Testing Old Flex for Breaks.
This is done by bending it inch by inch as shown.

"Tracking Back"

It is the "tracking back" idea which is the secret of successful fault finding. Here is an example of it by a professional "Fault Finder" who "happened along" just after a local "expert" had departed declaring that the whole instrument would have to go back to the makers:—

Instrument.—A 5-valve radiogram of well-known make working on the power system of the house.

Symptoms.—Terrific crackling at odd periods—worse after dark than in day time.

Previous Treatment.—A new set of valves tried; all contacts checked up for looseness.

The fault finder did not immediately start to pull the set to bits chiefly because he had

Fig. 3.—How to Prevent Microphonic Noises in Valves.
This can often be cured by packing the valves with cotton wool.

called for tennis and not for mending radio sets.

The crackle sounded exactly like that due to a faulty switch or lamp contact, the minutest sparks from which are capable of transmitting interference.

This was his bit of tracking back :—

Action.	Reason.	Result.	Conclusion.
Took out aerial and earth plugs.	To see if crackle was inside or outside set.	Crackle continued.	Crackle inside set or supply, *i.e.*, not coming down aerial.
Switched off lights throughout house.	To see if crackle was due to a bad contact in the lighting system.	Crackle much reduced but occasional bursts.	Some trouble in the lighting wiring of the house but not all.
Switched on every light in house and turned off each in turn until crackle stopped.	To see which light was giving trouble.	Most of crackle stopped on switching off both top landing lights and box room light. No reduction if only one switched off.	Interference due to lighting located in circuit common to box room and top landing lights.
Examined fuse box.	To try to isolate circuit of two lamps.	Found corroded fuse contacts in current feeding two lights in question.	
Cured crackle due to lighting circuit by new fuse wire and cleaning contacts.			
Took plug of radio out of power and connected to lighting socket.	To find out whether the remainder of crackle was in the set or power circuit.	Crackle still there.	Remainder of crackle in set.
Carefully twisted supply cord to set in the fingers inch by inch.	To find if there was a hidden break in the supply cord.	Found an intermittent disconnection in cord 8 inches from set. TROUBLE CURED.	

speaker wiring ; extra aerial leads all over the house, and volume controls dotted about in astonishing places are a few of the things which may cause trouble.

Clear the Decks for Action

Disconnect any odd wiring and bright ideas in the way of pick-up arrangements and comic gadgets, and start on the set connected up to its aerial and earth and *your own earphones* or loud speaker—one of those " Baby " speakers only made two or three years ago can be picked up dirt cheap and it is very handy to have by you —it is not much good testing out on a dud speaker ! but it wouldn't be the first time it had been done !

Let us consider a typical job and see where some of the " taken for granted " danger points are.

Elimination

Elimination step by step is the secret of all fault finding and applies to any kind of apparatus whether it is an electric bell, a radio set, or a motor car.

Look out for one or all of the following :—

(1) A break somewhere.
(2) A leak somewhere.
(3) A short circuit.

Most modern installations are fairly straightforward, but one does occasionally strike some old ones, and, as often as not, the trouble lies in one of the innumerable gadgets which, in the past, grew like whiskers on to many otherwise self-respecting sets. Weird additional loud

The Aerial

Is the aerial *really* O.K. ? Or is the unfortunate set trying to give decent results on the down lead only, because the joint between that and the aerial has gone, although by hanging on by a shred of insulation it looks O.K. ?

Lightning Switch

Is the lightning switch (if there is one) a common lodging-house for every kind of spider? Or completely smothered in dirt or rain ?

The Earth

Make enquiries about the earth. Track it out and see that the wire really is continuous—many wires after existing in the jambs of doors and windows for a year or two most certainly are not! Or if they are, the point where they are attached to the water pipe, or enter the ground, will provide you with an unpleasant surprise — very few earths are properly fixed to the earthing point, and many so-called earthing points are anything but efficient.

Nothing can look so respectably intact—if a little crushed—than an earth wire sitting smugly in the jamb of a window under three or four seasons of paint !

Fig. 4.—A Possible Cause of Trouble.
A broken spring in a valve holder can be the cause of many stoppages.

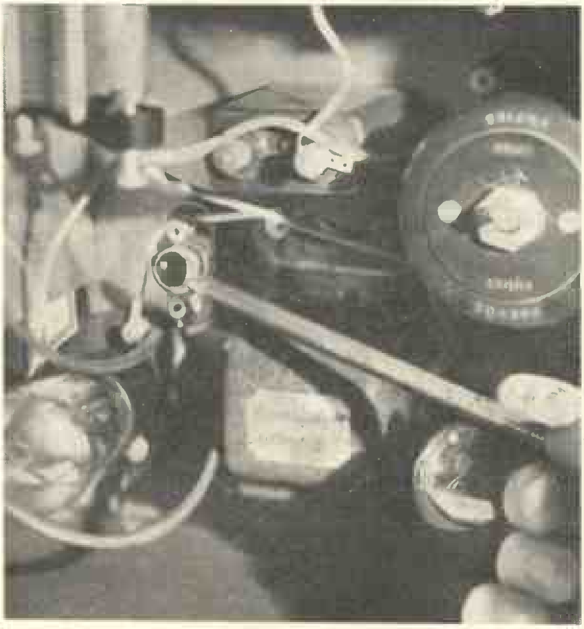


Fig. 5.—What to do if the Valves do not Light.
If the valves fail to light make sure that the fuse bulb is not broken.

Keep the Earth and Aerial Apart

If you find the earth wire neatly twisted up with the aerial wire, untwist it at once and put it *at least* a foot away, but don't say anything about the fool who put it in, because no one likes to feel that he has been had, however true he knows it to be, apart from the fact that he may have done it himself !

The Loud Speaker

Don't assume that the loud speaker is O.K., especially if the job is a fairly old one. The older types of loud speakers have a habit of losing their magnetism in an unobtrusive way, and it is in these cases that a small loud speaker or at least a pair of phones are an essential part of the Fault Finder's kit.

Intermittent breaks or shorts in loud speaker leads must be looked out for by moving the cords this way and that. Any leads which lie round a room get damaged. Don't forget that a break may be *inside* the insulation.

"Comic" Wiring

Take good care to disconnect any weird additional loud speaker leads when you are getting the set right. These leads have frequently been connected by inexperienced people, and are often full of danger points which, especially if they are not spotted when the set is being examined, may give rise to the most confusing symptoms.

The Sort of thing that can happen

I remember one case where an extra pair of leads had been taken to a small summer house for the use of an invalid, in addition to six other rooms in the house. A maddening intermittent failure was traced to the wind causing the wires to short on to the metal window frame of the summer house. This affected two other loud speakers in the house!

The Dry Batteries

Always test all batteries, both connected to the set with the set switched on *with a loud speaker connected*, and disconnected from the set.

A run-down dry battery may give quite a decent voltage reading after it has had a rest overnight, but look very sorry for itself after the set has been switched on for even a minute or so.

Fig. 6.—A TEMPORARY MEANS OF REMOVING DUST FROM THE GAP OF A MOVING COIL SPEAKER.

This temporary measure can be tried until the cone can be removed and the gap cleaned with a strip of plasticene.

Accumulators

See that the L.T. battery is O.K. by taking a voltmeter reading with the set switched on.

The Leaky Set

If the battery is clearly run down, find out before you connect a new one how long that battery has been in use. If for only a short time make certain that there is no leak anywhere inside the set—may be a condenser down to earth is leaky. This not infrequently happens in cheap portable sets, and one way of finding out is to connect up the H.T. battery, take out the valves, switch on and take a current reading between the H.T. neg. plug and socket. If there is anything there test each positive plug and socket separately to find out in which section of the circuit the trouble is, bearing in mind, by the way, that there may be a slight normal drainage due to the presence of a volume control, or some such arrangement. Look at the theoretical diagram carefully.

SOME "DO'S" AND "DON'TS"

Do's

(1) Always find out as much about the job as you possibly can before you set out.

Is it battery or mains driven?

FAULT TRACING CHART

Symptom.		Probable Cause.
Weak signals	Battery	Incorrect tapping. Low in voltage. Accumulator connected wrong way round. Accumulator down. Grid bias incorrectly connected.
	Aerial	Poor insulation. Bad position of aerial—wrong direction, screened, or too close to building. Faulty continuity of aerial or lead-in wire. Broken insulators. Dirty lightning switch.
	Earth	Faulty or " dry " earth. Poor continuity. Earth lead too near aerial. Aerial and earth wires reversed.
	Adjustments	Incorrect mains voltage. Incorrect voltage adjustment. Tags off screened grid H.F. valves. Tuning condensers out of gang. Valves in wrong positions. Valves not making proper contact with holders. Unsuitable valves. Defective valves—low emission. defective internally. contacts to pins faulty. No screen volts on H.F. valve Reaction circuit "dis."
Set absolutely " dead."	Batteries O.K. ?	Dead cell ? Connections right way round ? Accumulator charged ? All contacts clean and secure ? Leads O.K. ? Internal short ?
	H.T. wiring to valves O.K.?	Plugs and sockets O.K. ? Valve legs making contact correctly in holder ? L.F. transformer windings O.K. ?
	Loud speaker O.K. ?	Check adjustment. Check continuity. Check leads. Check sensitivity against own speaker.
	Valves burnt out due to incorrect connection of batteries ?	

	Output transformer faulty ?	If transformer is in anode circuit of output valve there will be no H.T. on anode of valve if primary is burnt out. Check continuity of winding and leads.
	Faulty loud speaker winding or leads.	Check continuity of winding and leads.
	Rectifier valve filament touching plates ? Signs of overheating of mains transformer. Rectifier valve burnt out ?	Check for contact between filament pins and anode pins of valves. Check continuity of filaments. Check fil. voltage at holder. Emission may be down. Try new valve.
VALVES LIGHT (*Note.* — In certain modern valves no glow is visible, but in most cases of mains valves the valve should be slightly warm. If in doubt check voltages at holder and continuity of valve filaments or heaters.	Rectifier valve emission faulty ?	
	Aerial and earth O.K. ?	
	Shorted " H.T. to E." condenser ?	Evidence of overheating in mains transformer by smell and observation. Disconnect main H.T. lead and test for output.
	Short in high tension leads ?	Rectifier valve very hot.
	Output valve fil. or heater O.K. ?	Check voltages at valve and continuity. Change valve if voltages present.
	Output valve H.T. O.K. ?	Check continuity.
	H.T. — feed wire dis ?	Check continuity.
	H.T. + feeder wire dis somewhere ?	Check continuity.
	Burnt out smoothing choke Shorted smoothing condenser.	Check continuity, having tested for voltage on either side of the choke—a good voltmeter will show a voltage drop across it if H.T. current is flowing through it.
	Voltage adjustment O.K.?	Watch and enquire for large variations in mains supply voltage.

	Voltage regulator lamp or resistance " dis." Or loose (D.C. sets) ?	
	Set switch O.K. ?	
	Supply socket and switch O.K. ?	
Valves do *not* light ?— (*Note.*—In some modern valves no glow is visible, in which case test at valve holders for voltage and check continuity of valve filaments and heater.)	House fuses and switch O.K. ?	
	Set fuses O.K. (if fitted) ?	
	Connecting flex O.K. ?	Internal break ? Connection inside plug ? Plug pins making contact ?
	Mains transformer primary O.K. ?	
	Voltage adjustment loose ?	
	Valve fils. and transformer fil. windings O.K. ?	
	Accumulator O.K. ?	
	Fil. resistance contacts O.K.?	
	Valve pins making contact with holder ?	

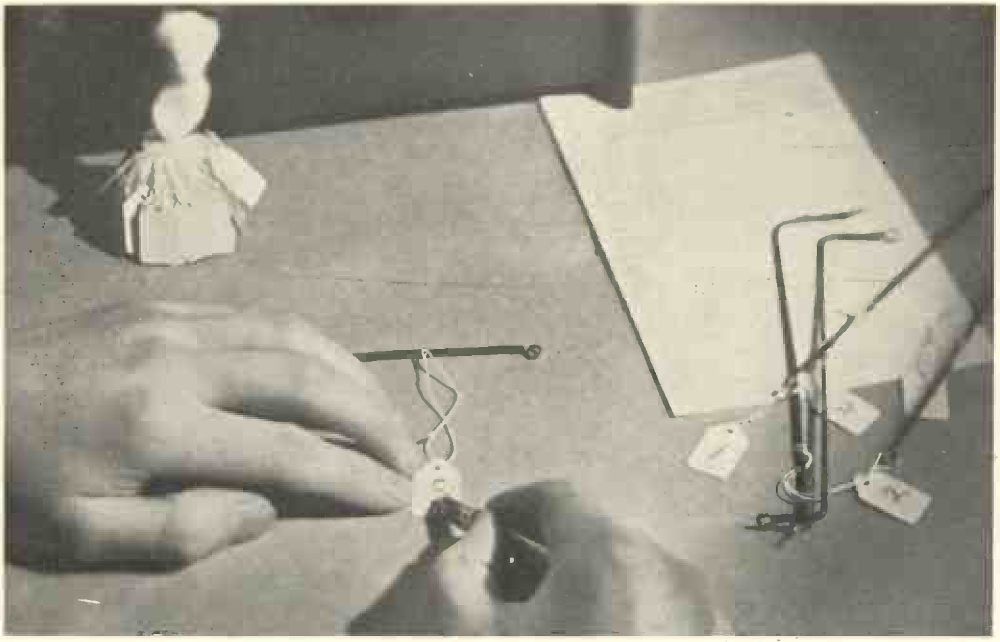


Fig. 7.—A HANDY TIP WHEN DISMANTLING A RECEIVER.
As each wire is removed it should be labelled as shown. This will make reassembly easy and rapid.

- **Distorted Reception**
  - Inside the set—
    - Volume control too far advanced.
    - Faulty valve (probably not H.F. valve).
    - *Incorrect tap on H.T. battery.*
    - *No or incorrect grid bias.*
    - Rectifier valve.
    - Faulty coupling transformers.
    - Leak between windings in transformers.
    - Leaky coupling condenser in resistance capacity sets.
    - Self oscillation due to unstable set.
    - Screening defective producing self-oscillation.
  - Associated Equipment.
    - Loud speaker out of adjustment.
    - Dust in gap of moving coil loud speaker (clean out with thin strips of plasticine).
    - Distortion on gram—
      - Pick-up output too high.
      - Incorrect or no volume control.
      - Dust in pick-up.
      - Pick-up armature jammed.
    - Low pitched quality
      - Too many additional loud speakers.
      - Incorrect volume control across output.
    - Grid leak faulty.
  - Outside the set —
    - Interference in a nearby receiver in a state of oscillation.
    - Heterodyne interference on programme by another transmitter.
    - Too powerful a signal from a nearby transmitter—aerial too long ?

Howling Whistle.

- Inside the set
  - Reaction too far advanced, if pitch varies (vol.) with turning of tuning control.
  - Microphonic valve—probably H.F. or detector—pack with cotton wool. (A howl which gradually builds up.)
  - Run-down H.T. battery.
  - Faulty detector valve.
- Associated Equipment.
  - Loud speaker too near set.
- Outside the set
  - Continuous whistle unaffected by tuning, probably interference on programmes by another transmitter.
  - Whistling or " whooping " varying in pitch but unaffected by tuning, probably interference by nearby receiver in a state of oscillation.
  - Pick up leads too near loud speaker leads.

Hum

- Inside the set
  - Open grid circuit—probably detector valve.
  - " Dis " smoothing condenser.
  - Short circuited smoothing choke or resistance.
  - Faulty rectifier valve (sometimes more of a purring sound).
  - Mains adjustment incorrect (set too high).
  - Loose laminations of the smoothing choke or mains transformer.
  - Hum control wrongly adjusted (if fitted).
  - Faulty valve (microphonic).
  - In A.C. mains sets filament or heater wires too near grid wiring.
  - Bad earth.
  - Mains plug in wrong way—reverse it (A.C. sets only).
- Associated equipment
  - Aerial lead running close to an A.C. power lead.
  - On " gram," pick-up leads not screened.
  - Loud speaker leads not screened or too near wires carrying A.C.
  - Interaction between loud speaker and set—move loud speaker away from set.
- Outside causes
  - During silent intervals the carrier wave of a powerful nearby transmitter (tuneable).
  - Electric motors.

NOISES.

(Don't assume that the trouble is necessarily *in* the set.)

Crackle, Scratching

- Inside the set
  - Faulty fixed condenser.
  - Loose valves or holders.
  - Faulty valve or holders.
  - Faulty volume control.
  - Bad contact in wiring.
  - Loose pilot lamps.
  - Faulty coupling condenser in R.C. amplifier.
  - Faulty mains leads or plugs.
  - Loose voltage adjustment.
  - Dust between vanes of tuning condensers (more likely in old types of sets).
  - Dirty switches or too light contacts.

Note.—Disconnect the aerial and see if noise stops.

- Associated equipment.
  - Faulty aerial and earth contacts or wiring.
  - Loose lightning switch.
  - Aerial touching something (trees, guttering, house).
  - Loud speaker and leads.
  - Extension wiring (aerial, loud speaker, pick-up).
  - Loose battery plugs.
  - Loose or dirty accumulator contacts.
  - Loose aerial and earth plugs.
  - Faulty house wiring (switches, lamps, fuses, plugs, radiators).
- Outside causes
  - Natural causes—Such as lightning—disconnect aerial to check if actually coming down aerial or trouble is in set.
  - Electrical apparatus (*Note.*—The B.B.C. are interested in outside interference and have a special Questionnaire Form available on request)
    - Motors
    - Electric signs (Neon or flashing).
    - Trams
    - Dynamos.
    - X-ray and Violet Ray apparatus.
    - Leaky mains.
    - Fans.
    - Motor ignition (mostly on short-wave sets).

How many valves?
How long have they been in use?
What are the valves?
Are they 2-volt, 4-volt or 6-volt?
How did the set go wrong? (Did it fade out or was there a sudden stoppage?)
What is the loud speaker?
When was the accumulator last charged?
How old is the set? The accumulator? The batteries?

(2) Always make helpful suggestions over the phone if you can.

(3) Always take spare valves (a complete set), but don't put them in right away if you find that the old ones are burnt out.

(4) Always check your service kit over

Fig. 8.—To avoid Mess of any Kind, a Small Silk Dust Sheet will be found useful.

before answering a "call." Always check your kit over before you leave.

(5) Always take an accumulator and H.T. and grid batteries which you know are O.K.

(6) Always keep a complete life history of every instrument you touch.

(7) Always take a theoretical diagram, if you can—a telegram or phone message to the makers of the set will bring you one by the next post—it's worth it.

(8) Always try to take another set of some kind with you to keep your clients happy in case you have to take their instrument away to service it. Your motto should be, "On with the Show."

(9) If the job is at all complicated always try to get the instrument away with you so that you can study it undisturbed—this is where the value of the loan set comes in.

(10) Always make a note of evidence of "tampering" and point it out discreetly.

(11) Always say as little as possible.

(12) Always avoid mess of any kind. Take a small silk dust sheet with you—it will be appreciated and does not take up much room in your kit.

Fig. 9.—A Faulty Down-lead that may give Trouble.

This down-lead has frayed (possibly by reason of an unnoticed nick in the wire when erecting), and only one strand remains in use. Similar trouble arises from corrosion of earth wires.

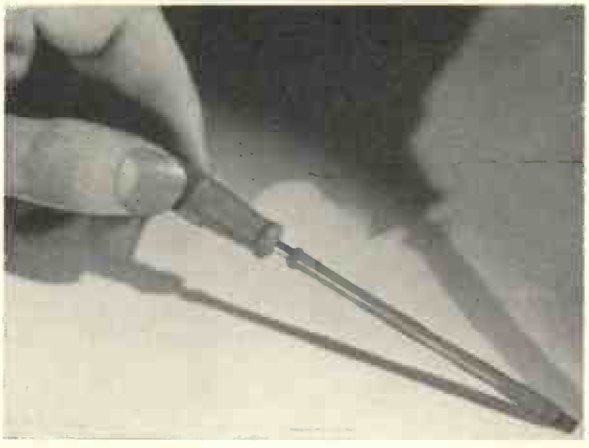


Fig. 10.—A Thin Screwdriver insulated by Rubber Tubing is Useful for Tinkering about Inside a Set.

(13) Always carefully label any wires you have to remove with small pieces of card, of which you should have a supply. Don't use paper—it falls off.

Don'ts

Don't appear over-confident.

Don't jump to conclusions.

Don't appear to hurry.

Don't make tests on the loud speaker until you are satisfied on phones. You don't want the owner to hear every squeak and howl as the set wakes up again.

Don't work without a theoretical diagram—if you can help it.

Don't borrow anything from the owner of the set—it looks bad. See that your outfit is complete before you set out, and that you have some money for any necessary small purchases.

Don't forget that one fault may be the cause of another, *e.g.*, a shorting rectifier valve may cause a burnt out mains transformer.

Don't leave a job without checking over, and if necessary, pointing out such things as worn flex leads, aerials and earths needing repair, or anything likely shortly to give trouble after you have left.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION V—MAGNETISM

THERE is to be found in Asia Minor a natural mineral which has remarkable properties. It attracts pieces of iron. The bigger the piece of this mineral the stronger is its attraction.

Just as electricity was discovered with the help of a natural product—amber, so did magnetite give rise to a new branch of the science of electricity called magnetism.

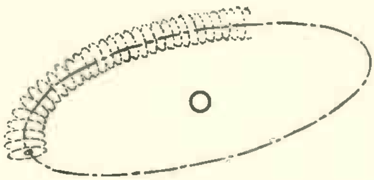


Fig. 1.—THIS SHOWS PART OF THE MAGNETIC FIELD AROUND AN ELECTRONIC ORBIT.

The electron whirls round so rapidly that the magnetic field is pulsating around the whole orbit.

What Magnetite consists of

Magnetite is a form of an oxide of iron consisting of three atoms of iron, which is a chemical element, and four atoms of oxygen. This can be represented chemically as Fe_3O_4. Another name for magnetite is Lodestone (leading stone). Why it is called a leading stone we shall discover a little later.

Not only does magnetite attract pieces of iron, but it communicates its properties to pieces of iron, steel, cobalt and nickel and makes them magnetic, too, on contact, when the latter are stroked by it in a certain way.

Magnetism can be communicated by Contact

Thus, as we see, magnetism can be communicated by contact just as electrification can be communicated from one body to another by contact.

Magnetic Induction

Similarly, if a piece of magnetite is placed near a piece of iron, the latter will become magnetised *at a distance* just as a conductor can be electrified at a distance. This latter phenomenon is called *magnetic induction.*

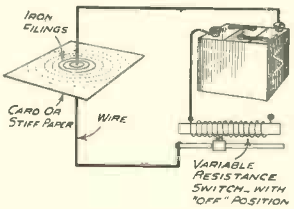


Fig. 2.—A PRACTICAL DEMONSTRATION.

Simple apparatus as above can be used to demonstrate the magnetic field round a wire carrying current.

Similarity between Magnetised and Electrified Bodies

Thus it is apparent that there is a great deal of similarity in the behaviour of magnetised bodies and electrified bodies. One cannot help wondering if there is not a common cause of the two sets of phenomena.

Again, if we take two similar pieces of steel and magnetise them by stroking each in turn with a piece of magnetite, we shall have two similar magnets. On bringing the ends of our two magnets together we shall discover that one pair of ends *attract* each other and another pair of ends *repel* each other.

This again reminds us very forcibly of the behaviour of electrified bodies. It looks as if there are not only two different kinds of electricity, but also two different kinds of magnetism.

Magnetic Direction

Somebody had a brilliant idea of making a small steel magnetic needle and suspending it on a fine thread so that it was free to swing in space. In this way it was found that the needle, provided there were no other magnets near, always placed itself in the same direction, namely, pointing in the direction of the geographical north and south. It is true that the direction of the magnetised needle did not coincide exactly with this geographical direction, being deflected some-

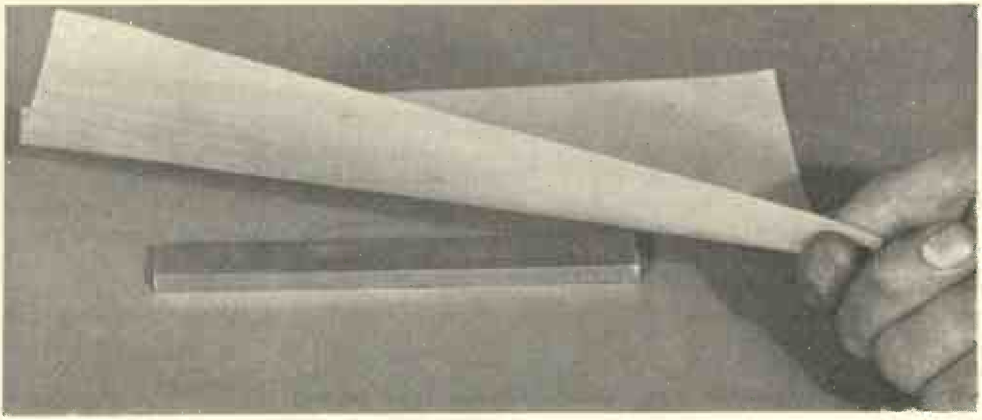


Fig. 3.—Demonstrating Magnetic Fields.
First place a sheet of paraffined paper over a bar magnet.

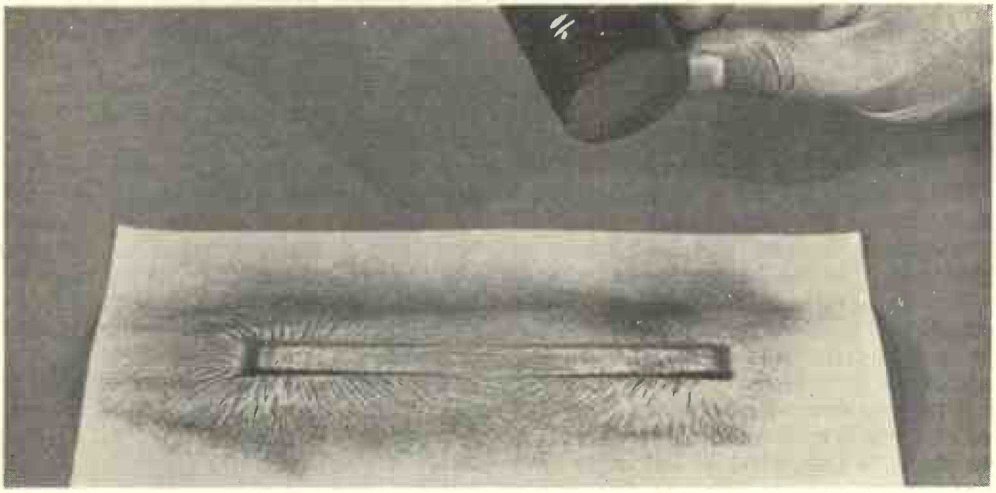


Fig. 4.—Demonstrating Magnetic Fields.
Next sprinkle iron filings over the paper as shown.

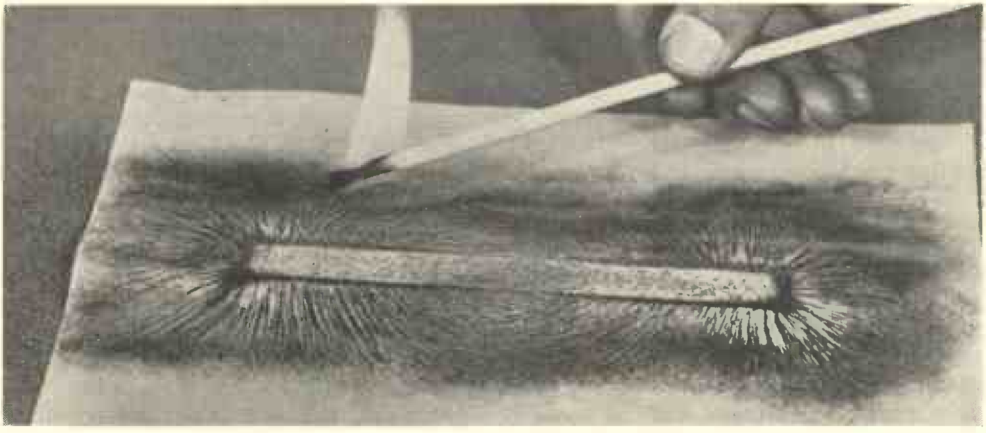


Fig. 5.—Demonstrating Magnetic Fields.
Use a taper to melt the paraffin, thus fixing the filings in position.

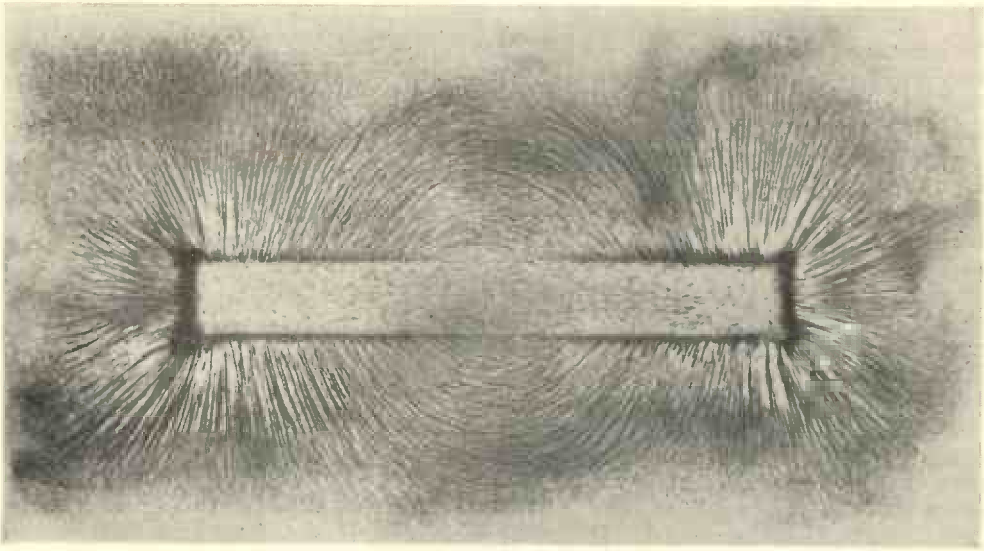


Fig. 6.—DEMONSTRATING MAGNETIC FIELDS.

This photograph shows clearly the magnetic conditions existing round a flat bar magnet. Notice how the lines of magnetic force radiate from each pole and also the formation round the centre of the bar.

what to one side, but it was near enough and persistent enough to indicate that the magnetic direction had something to do with the earth's north and south.

The end of the magnetic needle which pointed in the direction of the geographical north was called the *north seeking*, or simply the north end of the needle, and the opposite end, which always pointed south was called the *south seeking* end or simply the south end.

Why we speak of the Pole of a Magnet

This difference between the behaviour of the ends of the magnet being established, it was further discovered that the actual seat of magnetism was not at the end of the needle but a little distance away from the edge, nearer to the centre, and for this reason scientists do not talk about the end of the magnet but the *pole* of a magnet. The word pole also conveys the meaning that a magnetic needle points towards the north pole and the south pole.

This property of the magnet to be able to point *always* in the same direction when suspended freely in space or mounted on a pin point, free to rotate, proved to be a very useful method of direction-finding by mariners at sea, and thus the modern compass came into existence.

This is the reason why magnetite, a small piece of which will behave in precisely the same manner, has been called the leading stone or lodestone.

Natural and Artificial Magnets

Magnetite, which is a natural ore, is called a *natural magnet*. A piece of steel stroked with magnetite or magnetised by some other means is called an *artificial magnet*. As a matter of fact, it is possible to make artificial magnets of greater strength than a natural magnet of the same size can ever be.

The commercial method of producing magnets involves the use of special magnetising apparatus. A very powerful electro-magnet is energised from D.C. mains, and the article or articles to be magnetised are placed in position across the poles of this electro-magnet. It is found that the composition of the steel used for making permanent magnets affects their efficiency very greatly. Slight additions of other metals, such as tungsten, enable the steel to be magnetised more strongly and to retain its magnetism for a much longer period.

If a steel darning needle is magnetised and gently broken into two, each half will prove to be a complete magnet. Similarly if the halves are broken into two, each quarter will prove to be a complete magnet. If this division is carried out far enough we shall find that *each molecule is a complete magnet*. Why a molecule should be a magnet in a magnetised substance we shall discover a little later, but in the meantime let us visualise each molecule as being a natural magnet, possessing two poles, a north and a south pole.

Elements which show strong Magnetic Properties

As it has already been mentioned, only three chemical elements show strong magnetic properties: iron (and steel which is a combination of iron, carbon, etc.), cobalt and nickel. The remaining substances possess magnetism in a very small degree or none at all. But it is a known fact that all substances are either attracted or repelled by a strong magnetic pole.

All elements were studied from this point of view, and to distinguish between the two classes of materials, those which are attracted by a strong magnetic pole are called *paramagnetic elements*, to which amongst others belong oxygen, aluminium, chromium, tin, tungsten and platinum.

The materials which are repelled by a magnetic pole are called *diamagnetic elements*, to which belong carbon, sulphur, copper, zinc, &c.

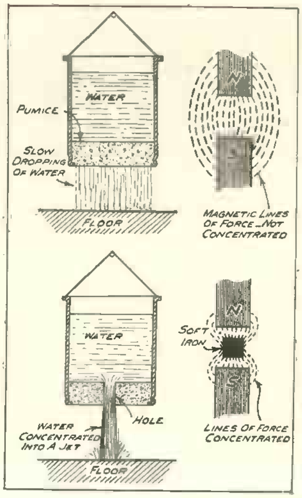


Fig. 7.—A Simple Analogy between the Mechanical Effect of a Hole in a Water Vessel and the Magnetic Effect of a Piece of Iron in the Lines of Force.

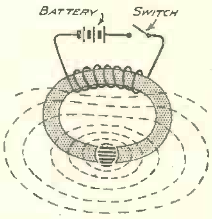


Fig. 8.—The Armature in Its Simplest Form.

It can be seen from the previous analogy that a piece of soft iron placed between the poles of this ring magnet would concentrate the magnetic lines across the air gaps.

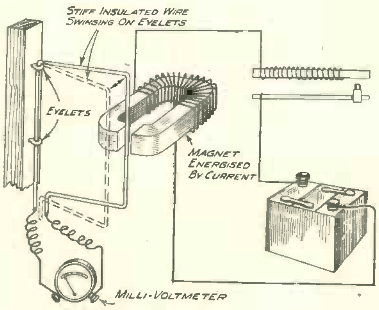


Fig. 9.—A Simple Form of Electric Generator.

Three Distinct Classes

As you see, from the magnetic point of view, we divide the chemical elements into three distinct classes: *Magnetic elements* (iron, cobalt and nickel), *paramagnetic elements* and *diamagnetic elements*. It is interesting to note that, amongst the conductors of electricity, aluminium, tin, tungsten and platinum are paramagnetic (attracted to a magnetic pole), and carbon, copper, zinc, silver, gold, mercury and lead are diamagnetic.

Difference between Magnetised and Non Magnetised Substances

It would thus appear that the difference between a magnetised substance and non-magnetised substance, since every molecule is a natural magnet, is the question of orientation of molecules.

In order to obtain a distinctly magnetised substance it is necessary to turn all the molecules in the substance so that all their north poles point in one direction and all their south poles point in the opposite direction. We can imagine the molecules in a non-magnetised substance as a disorderly mob facing in all possible directions, and in a magnetised substance the molecules behave like soldiers on parade, and all face the same way as soon as the sergeant-major "Magnetising Force" gives the word of command.

It appears, to continue the analogy, that discipline is best in the case of magnetic ele-

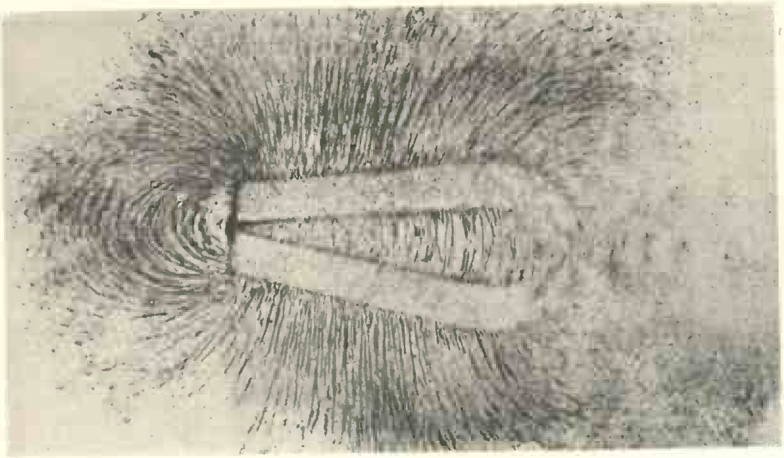


Fig. 10.—MAGNETIC FIELD ROUND A HORSE-SHOE MAGNET.

This photograph was prepared in the same manner as that illustrated in Figs. 3 to 6. It shows the distribution of magnetic force round a horseshoe magnet. Notice how the magnetic field is concentrated between the north and south poles of the magnet.

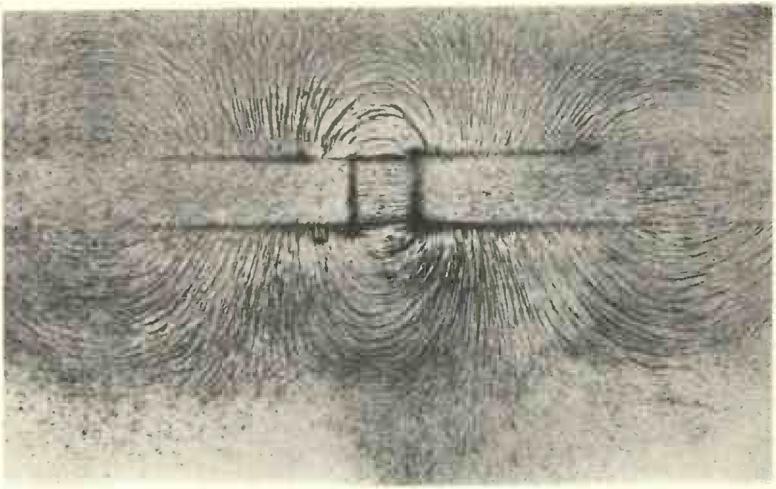


Fig. 11.—MAGNETIC FIELD BETWEEN NORTH AND SOUTH POLES.

Notice how the lines pass straight across the air gap between the two poles and then spread out in widening circles from the points more distant from each pole. This picture should be carefully compared with that shown in Fig. 12.

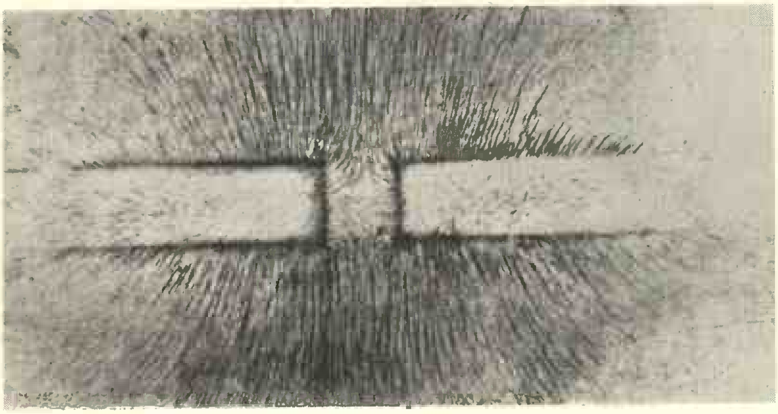


Fig. 12.—MAGNETIC FIELD BETWEEN TWO NORTH POLES.

Notice how in this case there is practically no magnetic flux in the air gap between the two poles, due to the fact that each pole exerts a repelling effect upon the other.

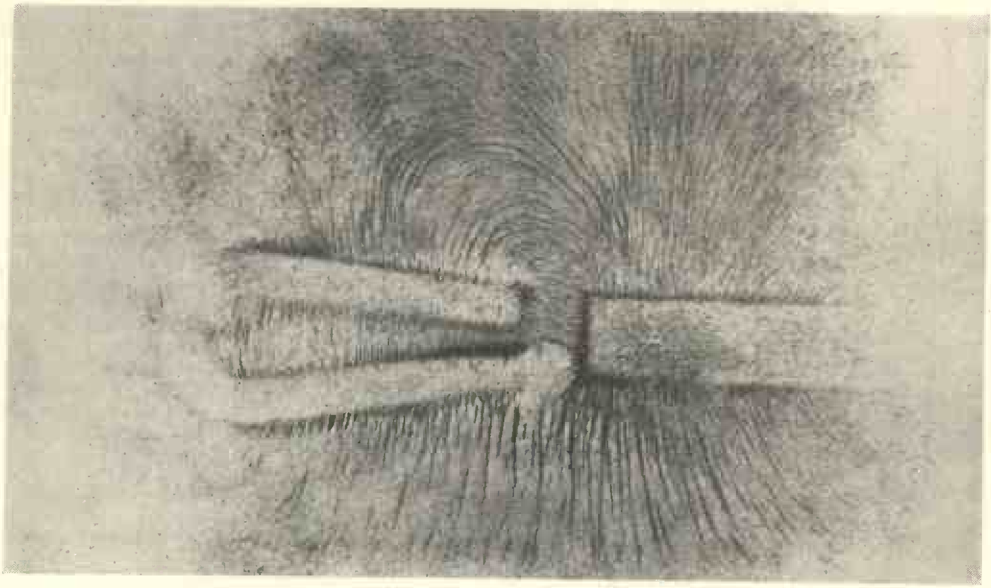


Fig. 13.—Another Interesting Picture.

Here we see a horseshoe magnet placed near the north pole of a bar magnet. Again it will be seen that there is a strong flux between north and south poles and an absence of flux between the two north poles.

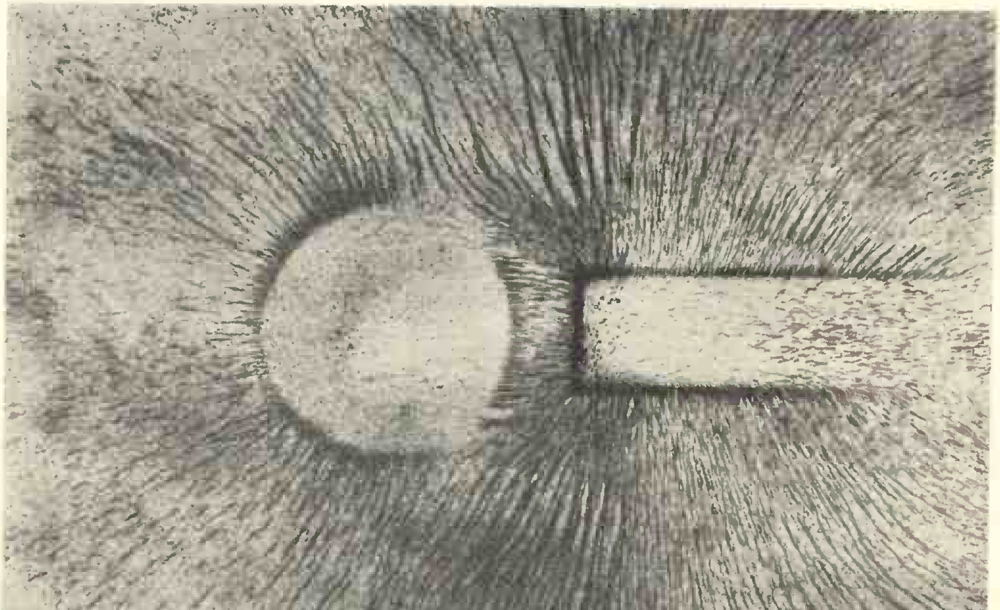


Fig. 14.—A most Important Demonstration.

The above picture shows the result obtained by placing a soft iron ring near one pole of a strong magnet. This shows very clearly that inside the ring the magnetic effect is nil. This is the underlying principle involved in all kinds of magnetic shielding appliances.

ments. It is rather weak in the case of paramagnetic substances, and is akin to rebellion in the case of diamagnetic substances. For this reason, for practical purposes, it is only iron (and steel), cobalt and nickel and their alloys that count.

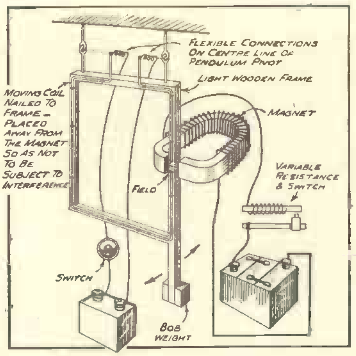


Fig. 15.—AN INTERESTING EXPERIMENT.

The swinging coil rapidly comes to rest when the electromagnet circuit and coil circuit are closed.

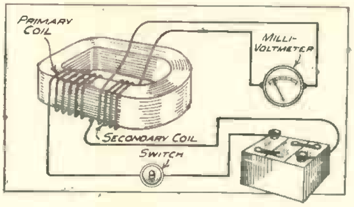


Fig. 16.—AN EXPERIMENT TO SHOW THAT A CURRENT CAN BE INDUCED IN A WIRE BY ANOTHER CIRCUIT.

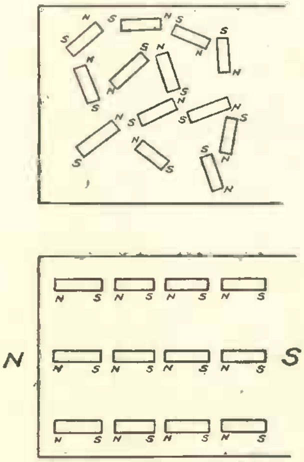


Fig. 17.—(*Top.*) When iron is not magnetised the molecules are pointing in all directions. (*Bottom.*) When iron is magnetised the molecules are arranged in orderly arrays all pointing the same way.

Magnetic Shielding

Now let us go a step further. It has been found that magnetic attraction manifests itself *through* substances. Thus, for instance, if we enclose a magnet inside a wooden or a glass case, it will attract and repel in spite of the wood or glass. The same thing will happen if a magnet is placed in vacuum. The only thing that will stop a magnetic influence to be felt is a box of iron, steel, cobalt or nickel. A magnetic substance completely surrounding a magnet will stop its influence being felt outside the boundaries of its own walls. This is called *magnetic shielding*.

In order to be able to understand the meaning of the phenomenon of magnetic shielding, let us consider another aspect of magnetism. There is something happening to the space surrounding a magnet. Since we saw that magnetism operates in vacuum, it means that magnetism is something happening in the ether, which is the third constituent of our universe, the other two being the electron and the proton.

The Magnetic Field

It is very fortunate that we can see what is happening around the magnet. Take an artificial magnet, place a piece of paper over it and sprinkle over the paper some very fine iron filings from a discarded pepper pot or a glass bottle with a tin perforated top, and you will find that the iron filings will place themselves always in the same way, forming a peculiar but orderly pattern of curved lines. This pattern, consisting of a number of lines, is called the *magnetic field*.

Lines of Magnetic Force

The word *field* is a little misleading to the novice, but it is used to mean the extent of space around a magnet in which its influence is felt. Such a field becomes less intense as it goes further and further away from the magnet. By turning the magnet round and placing it on each of its edges (I have in mind a rectangular bar-shaped magnet), you will find that this magnetic field exists all round the magnet. You have to think of a magnetic field surrounding a magnet as something happening in three dimensions, in other words, the lines constituting the magnetic field (or the lines of force of a magnetic field) are above and below the magnet and on each side, *i.e.*, all round it.

Many people do not appreciate this last point.

How the Lines of Force Flow from one Pole to the Other

In studying the magnetic field it is exceedingly interesting to see what

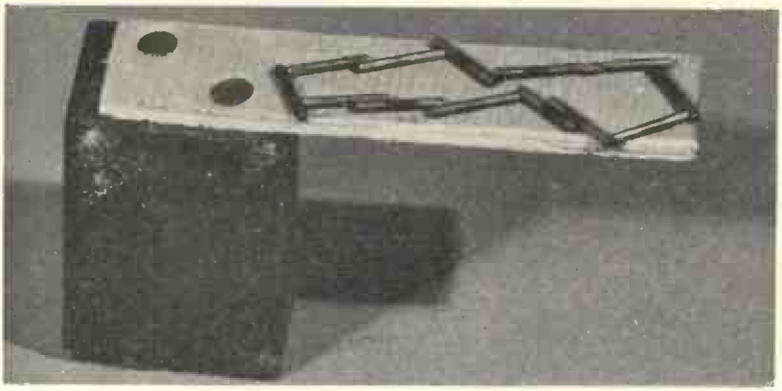


Fig. 18.—What Happens When a Piece of Iron is Magnetised.

Here we see a number of small bar magnets arranged horizontally on a wooden support. These represent the molecules in a bar of soft iron which has not been magnetised, *i.e.*, which exhibits no free magnetism.

happens in space when an attraction takes place between dissimilar poles, *i.e.*, a north and a south pole, and when repulsion takes place between similar poles, *i.e.*, two north or two south poles. You can actually see how the lines of force flow from one pole to the other in the case of attraction, and spread away from each other in the case of repulsion.

It is also interesting to see what happens to the lines of force in the case of magnetic induction.

What we have Learned so far

Having gone thus far, let us now put our ideas in connection with magnetism in order.

(1) There are three magnetic materials: iron (and steel), cobalt and nickel.

(2) There is a natural magnet called magnetite.

(3) We can produce a much stronger magnet than magnetite by making an artificial magnet.

(4) Each magnet has two poles, a north and a south one.

(5) Like poles repel each other, unlike poles attract each other.

(6) A magnet divided into two halves will result in two separate magnets.

(7) A magnet placed near and close to a piece of unmagnetised iron will make the latter a magnet by influence.

(8) A magnet suspended to swing freely in space will always point in the same direction.

(9) Each molecule is a magnet.

A Practical Demonstration

The experiments illustrated in Figs. 18, 19, 20, and 21 reproduce on an enlarged scale the

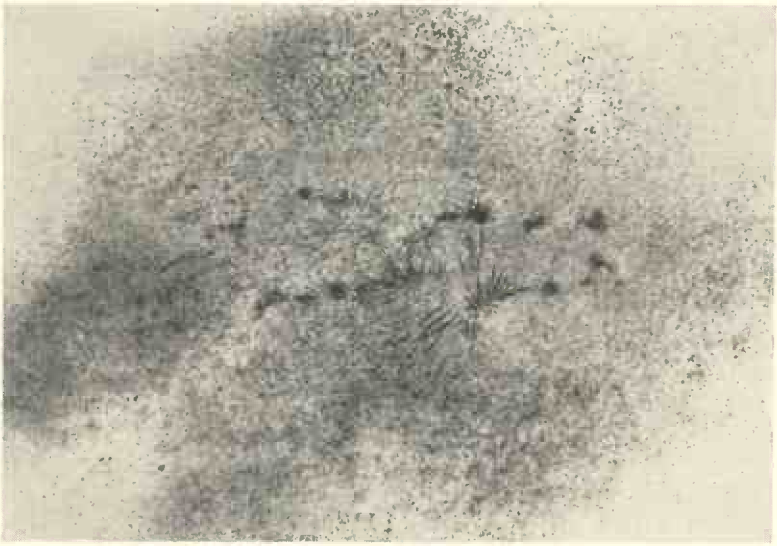


Fig. 19.—What Happens When a Piece of Iron is Magnetised.

The above picture shows the flux round the group of small magnets illustrated in Fig. 18. Notice that there is practically no free magnetism present.

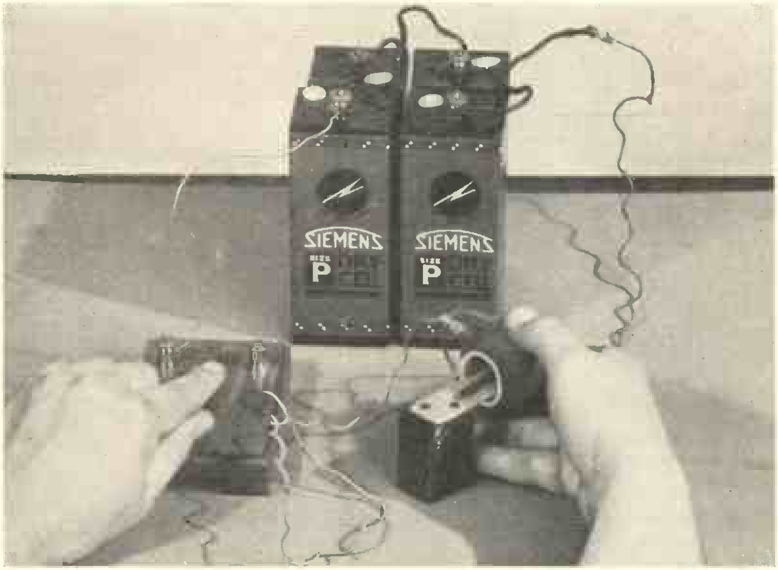


Fig. 20.—What Happens When a Piece of Iron is Magnetised.

A coil carrying a current has now been placed round the collection of bar magnets. Notice that they have taken up an orderly position along the axis of the coil.

effect which takes place when a bar of iron is magnetised. In these experiments small bar magnets had been used to represent the molecules in an iron bar, but it will be readily understood that if small magnetised iron pellets had been used instead the effect obtained would be still more striking. Even this crude experiment, however, suffices to demonstrate the effect obtained.

Difference in Behaviour of Iron and Steel

Now let us take the last three items in order of sequence. The difference in the behaviour of iron and steel is that the iron when magnetised does not retain its magnetism, and will remain magnetic only while under the influence of a magnetising force. Steel, once magnetised, will retain its magnetism for years, provided it is not subjected to violent mechanical shocks, rapid heating and cooling, *i.e.*, anything that will tend to shake the oriented molecules loose again.

If you remember when we placed an electrified body near a neutral body, an opposite charge was induced in the near end and a similar charge in the far end.

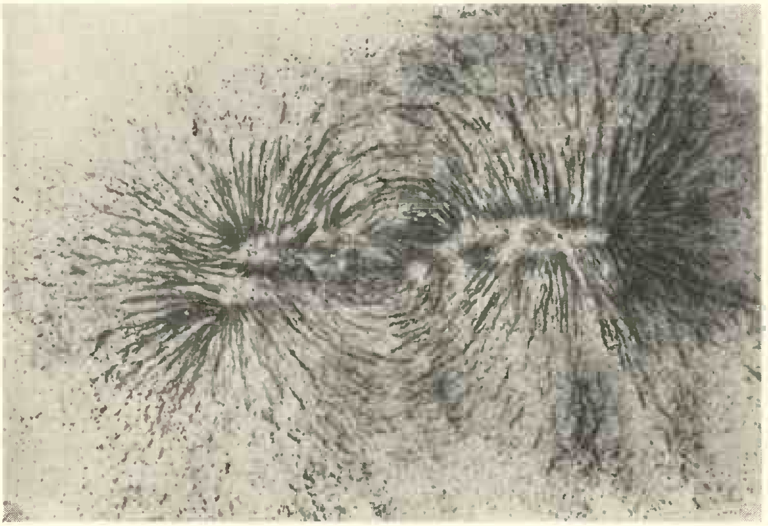


Fig. 21.—What Happens When a Piece of Iron is Magnetised.

Here we see the magnetic field round the bar magnets after they have been subjected to a magnetising force. Compare with Fig. 6.

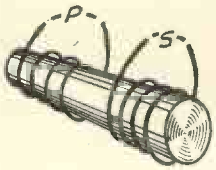


Fig. 22.—THE SIMPLEST TYPE OF TRANSFORMER.

The ratio between primary and secondary voltage depends on the number of turns in each winding.

What Happens in the Case of Magnetic Induction

A similar state of affairs prevails in the case of magnetic induction. When the north pole of a permanent (a new word indicating the permanency of magnetism in the case of a steel magnet) magnet is placed near a non-magnetised iron bar, the near end of the iron bar will show a south polarity, as if the north poles of the permanent magnet molecules were attracting towards themselves the south poles of the iron molecules and repelling in the opposite direction the north poles of these molecules, and the far end a north polarity.

If the permanent magnet is now turned round so that its south pole is near the piece of iron, the polarity of the latter will be reversed, the near end being a north pole and the far end being a south pole.

Why a Freely Suspended Magnet always Points in the Same Direction

We now know that a magnet suspended freely will always point in the same direction. The reason for this is that the earth containing large quantities of magnetite, as it does, together with other magnetic materials is a magnet in itself, having two poles, the north magnetic pole somewhat apart from the geographical north pole, and the south magnetic pole. Having in view the attraction of unlike poles, it is easy to understand that the north seeking pole of a magnet is really the south pole of the magnet which is being attracted by the north pole of the earth. But as from the early days of science the north seeking pole of a magnet has always been called the north pole, we shall stick to this name so as to avoid confusion. But this

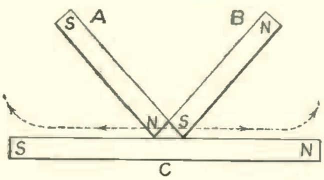


Fig. 24.—METHOD OF RE-MAGNETISING A BAR MAGNET.

point should be kept in mind in order to have a clear conception of magnetic attraction.

The fact that the earth is a magnet, and like any magnet has a magnetic field around it, is further confirmed by the fact that a freely suspended magnetic needle does not swing horizontally, but has one end pointing down somewhat below the horizontal line.

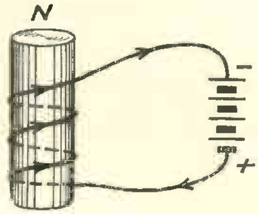


Fig. 23.—ILLUSTRATING THE CORKSCREW RULE.

This is a simple diagram, but a very important one. It shows a coil of wire wound round an iron core, and it also shows the position of the north pole corresponding to a certain direction of flow of the current. Remember that magnetic flux passes from south to north inside the magnet, then if the current flow is represented by the turning of a corkscrew the direction of the magnetic lines will be represented by the vertical motion of the corkscrew. In the picture above the corkscrew must be imagined as entering the core from the base.

Magnetic Dip

This attraction of a magnetic needle towards the surface of the earth, varying with the geographical position, is called the *magnetic dip*.

The Magnetic Field of the Earth

The earth magnetic field has to be taken into consideration when dealing with magnetic measurements, as it enters into combination with artificially produced magnetic fields. This is especially important in the case of magnetic measuring instruments, and precautions have to be taken to counteract the influence of terrestrial magnetism.

Cause of Magnetic Storms

Stars and other planets possess similar magnetic fields, and it remains to be seen what *rôle* these magnetic fields play in the gravitational phenomena, if they play any such *rôle* at all. But the sun's magnetic field is often the cause of considerable perturbation of the earth's magnetic field, causing what is known as *magnetic storms*, usually associated with sun spots, storms which cause a compass needle to swing about as if it has gone mad.

How the Polarity of a Magnet is Assessed

In assessing the polarity of a magnet we use a magnetic needle such as a compass needle with known polarity, and discover an unknown pole by the attraction or repulsion of a known pole.

Thus the compass needle does for us the same service as the electroscope performs in the case of detection of electrification and the nature of this electrification.

Molecular Magnetism

Now we come to the question of molecular magnetism. In the previous section of this work I mentioned the fact that an electric current, *i.e.*, a flow of electrons, will be the cause of the appearance of a magnetic field near the conductor through which a current is flowing. This is the magnetic effect of electrical currents.

It will be remembered that a series of simple experiments were shown in the first section to demonstrate some of the more important of the electro-magnetic actions which can be made to occur.

Lines of Force vary with Strength of Current

If we thread an insulated wire through a piece of stout paper, and having caused a current to flow through the wire sprinkle the paper with iron filings, we shall find that once more we have a magnetic field made up of a number of concentric circles (circles of varying radius drawn from the same centre) surrounding the wire. On varying the strength of the current we shall discover that as the current increases, more and more lines of force of the magnetic field will make their appearance, and the extent of space occupied by these lines will also increase. Thus, it is easy to see that the strength of the magnetic field grows with the strength of the electric current flowing in the wire.

Let us get this idea clear. Somehow or other an electric current produces a magnetic field around a conductor through which an electric current is flowing. The conductor itself is not magnetic, and has nothing to do with magnetism. It is only the space around that becomes magnetic.

An electric current which is made up of a number of electrons travelling within the conductor at some considerable speed causes some *disturbance in the ether* surrounding the conductor.

This disturbance of the ether is made visible with the help of iron filings sprinkled over a sheet of paper through which the conductor is threaded. It is clear therefore that a moving electron is capable of producing a magnetic field.

Why a Current Produces Magnetism

Now an electron rotating rapidly around the nucleus of its atom is a tiny electric current in space, and as such produces a small magnetic field around its own orbit. A number of electrons will thus produce a number of magnetic fields in the space surrounding the atom as a whole, and if the fields in question coincide in direction, *i.e.*, their polarity will add up, they will produce a comparatively strong magnetic field around the atom. In the case of a number of atoms comprising a molecule, different atoms will have different magnetic fields, and the latter may add up.

Why Different Substances have Different Magnetic Properties

In iron, in cobalt and nickel this addition of atomic magnetic fields appears to be very effective, and the molecule possesses a pronounced magnetic field, making the molecule as a whole a tiny magnet with two poles, north and south. In other substances the magnetic fields do not add so well, and the resultant molecular magnetic field is either weak or the opposing atomic magnetic fields neutralise each other so that there is no resultant magnetism apparent.

Another Proof of the Importance of understanding the Electron Theory

The above explains to some extent why some molecules are strongly magnetic and why others are only either attracted or repelled by a very strong magnetic field. The magnetism is always there ; it is only its intensity that varies, and at the bottom of it all is our old friend the electron, which appears now not only as the primary cause of electrical phenomena, but is also responsible for the magnetic phenomena.

Total Magnetic Flux

The intensity of the magnetic field is measured by the number of lines of force per unit area. The total number of lines of force between two poles being known as the total *magnetic flux*.

In conclusion let us see how artificial magnets are produced. To magnetise a bar of steel take two steel magnets and place in the middle of the bar under magnetisation two opposing poles, the north of one magnet and the south of the other magnet. Now stroke the bar from the middle, drawing one pole in one direction and the other pole in the opposite direction, away from the middle. Turn over the bar under magnetisation and repeat the process. Do this several times till the bar is strongly magnetised.

How Artificial Permanent Magnets are Produced

The best way to magnetise a steel bar magnet is to surround it with a coil of insulated wire and let a strong current flow in the coil for some time. This is the modern method of producing artificial permanent magnets.

The expression permanent magnets no doubt reminds you of the permanent magnet moving coil loud-speaker. As you see, magnetism has a direct application in wireless, and for this reason deserves careful study.

Next time we shall consider the question of electromagnetism, or in other words, we shall study the electrical effect of electrical currents in detail.

QUESTIONS AND ANSWERS

What is meant by the North Pole of a Compass Needle?

That end of the needle which when the needle is free to swing always points towards the magnetic north pole of the earth.

What is the difference between the Magnetic North Pole and the Geographic North Pole?

The geographical north pole is the one end of the imaginary axis about which the earth turns. The magnetic north pole is that point on the earth's surface to which compass needles point. It so happens that both these are fairly close together on the earth's surface.

What is the Law between Like and Unlike Magnetic Poles?

Like poles, *e.g.*, north and north repel each other. Unlike poles, viz., north and south attract each other.

What can you infer from the above regarding the Magnetic North Pole?

As a north pole of a compass needle always points towards the magnetic north pole it must be that the magnetic north pole is really a south pole if the earth is viewed as a large permanent magnet.

What other Metals can be Magnetised besides Iron?

Cobalt and nickel are all substances attracted by a strong magnet. It has been found that all substances are either attracted or repelled by a very strong magnetic pole. Iron, nickel, cobalt, oxygen, aluminium, tin, tungsten, and platinum are attracted, carbon, sulphur, copper, zinc, silver and several other metals are repelled.

What are Two Important Applications of Electromagnetic Effect in Wireless?

(*a*) The Low Frequency Transformer.
(*b*) The Telephone and Loud Speaker.

What is the Corkscrew Rule?

This is a rule which enables one to determine the north and south pole of an electro-magnet. Imagine a corkscrew being screwed into the core so that the direction of rotation corresponds with the direction of flow of current round the coil. Then the travel of the corkscrew shows the direction of the magnetic flux, *i.e.*, the point of the corkscrew will move towards the north pole of the magnet.

THE 7-METRE THREE

A THREE VALVE RECEIVER DESIGNED FOR USE ON VERY SHORT WAVELENGTHS

By FRANK PRESTON, F.R.A.

THE advantages of very short wavelengths, such as those below 10 metres, are not far to seek, and are readily apparent when it is realised that (allowing the recognised 10 kilocycle separation) 900 stations could be accommodated between 6 and 7 metres as against the paltry 100 between 200 and 500 metres. This fact is particularly significant in view of the present congestion of the wavelength ranges now in use for broadcasting.

With the further development of television, which seems inevitable, a wider range of frequencies will at once become necessary, since each transmitter will require two wavelengths, one for sound and the other for light (forming the image). It is pretty certain, therefore, that it will not be long before the wavelengths below 10 metres are in great demand.

It is, therefore, proposed to give practical details of a tested receiver which has been designed principally to cover a range of from 5 to 8 metres. It might be mentioned in passing, though, that the instrument is perfectly suitable for use on all wavelengths up to 80 metres or more by the substitution of suitable coils.

The Circuit

It will be seen from Fig. 8 that the circuit follows more or less standard practice, and employs a leaky-grid detector followed by two L.F. amplifying valves. Tuning and reaction circuits are on the Reinartz principle, this having proved most satisfactory in practice. A superheterodyne might have given slightly better results, but its cost would have been much higher,

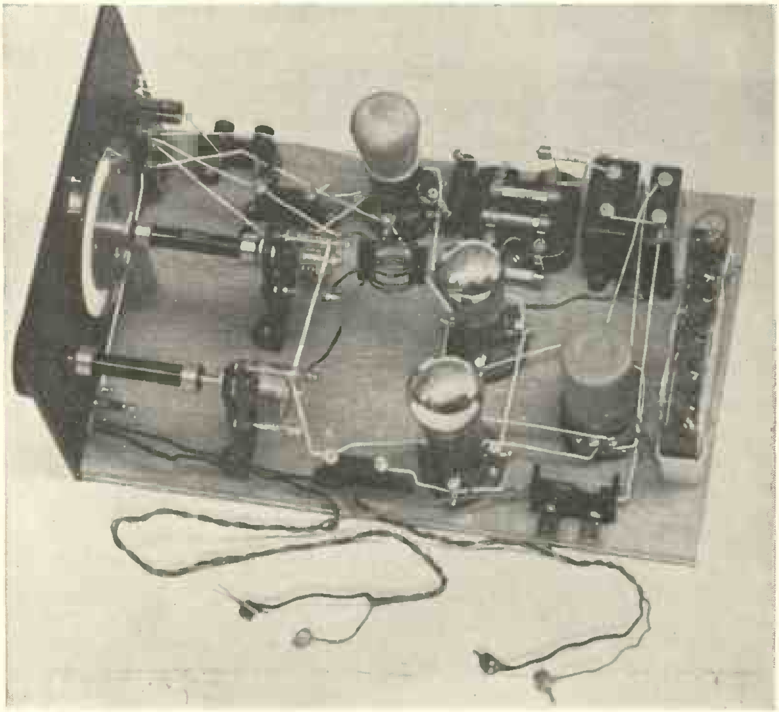


Fig. 1.—THE COMPLETE RECEIVER.

whilst the addition of a screened grid valve would confer no appreciable benefits, since the extra amplification available would be practically nil.

The aerial feeds into the tuned circuit through a very small (7 micro-microfarad) variable condenser. A 35 m.mfd. condenser tunes the aerial coil, whilst a 100 m.mfd. condenser is employed as a reaction control. The grid condenser is of ·0001 mfd. and a 5 megohm leak is used, because it is found that the higher value makes reaction control smoother besides adding less damping to the tuned circuit.

Why a Potentiometer is used

Instead of connecting the end of the grid leak to L.T. — or L.T. + in the usual manner, it is taken to the slider of a 250 ohm potentiometer wired across the L.T. supply. The potentiometer provides a useful "vernier" reaction control, and makes it possible to work the detector valve at maximum efficiency. The latter valve is shown as being of the "H.L." type and should have an impedance of about 15,000 ohms. A metallised valve is to be preferred since the screening is useful in maintaining stability.

De-coupling

In the detector anode circuit we have a short wave choke and a 50,000 ohm anode resistance, which forms part of a resistance - capacity - coupling unit. De - coupling is provided by a 30,000 ohm resistance and a 2 mfd. condenser. To prevent the passage of H.F. currents into the amplifier a ·25 megohm "stopping" resistance is included in the grid lead to the second valve.

The first L.F. valve (a type "L"), is coupled to the output power valve through a resistance-fed transformer of which

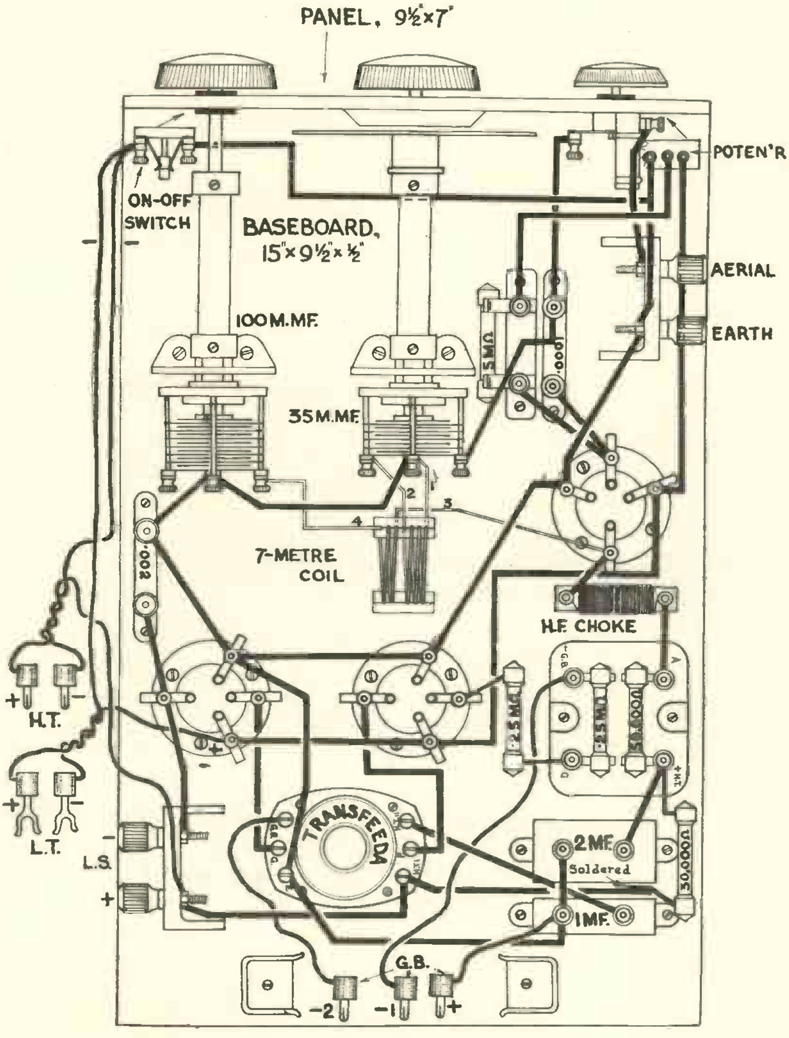


Fig. 2.—The Wiring Layout.

This shows every connection very clearly, and should enable the set to be constructed without difficulty.

one portion of the resistance is used in conjunction with a 1 mfd. condenser for de-coupling purposes. A ·002 mfd. condenser is joined between the anode of the power valve and earth, to prevent any stray H.F. currents from passing into the loud speaker leads.

Fig. 3.—THE CONTROL PANEL.

The Design

In designing the receiver, the first aim was to provide a really workable instrument which could be made at reasonable cost. For this reason all the components are of standard types, which are readily available. By following this course, all constructors are assured of a successful and efficient receiver by working to the illustrations given. Every component as well as the final assembly have been carefully tested, and there is absolutely nothing in the design which is "experimental," or of doubtful efficiency. This means that if a thousand sets are made to the drawings reproduced, each one should give similar results to the original.

List of Components Required

1 Panel, 9½ inches by 7 inches ("Vibranti" or ordinary plywood).
1 5-Ply Baseboard, 9½ inches by 15 inches.
1 7 m.mfd. Aerial Series Condenser (*Eddystone "Midget"*).
1 7-metre Coil (*Eddystone* or as on p. 229).
1 35 m.mfd. Variable Condenser (*Eddystone "Microdenser"*).
1 100 m.mfd. Variable Condenser with 2-inch knob (*Eddystone "Microdenser"*).
2 Condenser Extension Outfits (*Eddystone*).
1 Slow Motion Condenser Drive Assembly (*Eddystone*).
1 250 ohm. Potentiometer (*Colvern*).
1 On-off Switch (*Bulgin "Junior"*).
1 ·0001 mfd. Fixed Condenser (*T.C.C.*).
1 5 megohm. Grid Leak (*Dubilier "Metallised"*).
1 Grid Leak Holder (*Dubilier*).
3 Short Wave Valve Holders (*Eddystone*).
1 Ultra S.W. Choke (*Eddystone*).
1 R.C.C. Unit with 50,000 ohm Anode Resistance, and ·25 megohm Grid Leak (*Dubilier*).
1 30,000 ohm Metallised Resistance (*Dubilier 1 watt*).
1 ·25 megohm Metallised Resistance (*Dubilier 1 watt*).
1 L.F. Coupling Unit (*Benjamin "Transfeeda"*).
1 1 mfd. Fixed Condenser (*T.C.C.*).
1 2 mfd. Fixed Condenser (*T.C.C.*).
1 ·002 mfd. Fixed Condenser (*T.C.C.*).
2 Terminal Mounts (*Belling Lee*).
4 Terminals: marked "A," "E," "L.S. +" and "L.S. −" (*Belling Lee Type "R"*).
1 pair G.B. Battery Clips (*Bulgin*).
5 Wander Plugs; marked "H.T. +," "H.T. −," "G.B. +," "G.B.−1," and "G.B. − 2" (*Belling Lee*).
2 L.T. Spade Terminals (*Belling Lee*).

Approximate Cost £3 10s. od.

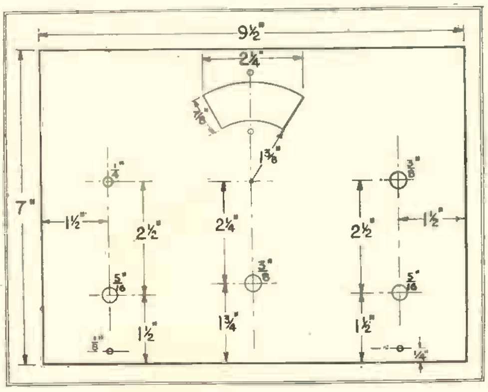


Fig. 4.—DETAILS OF DIMENSIONS FOR DRILLING PANEL.

3 Valves; 1, P.M. 1 H.L. (metallised); 1 P.M.1 L.F. and 1 P.M.2 (Mullard).

Constructors are strongly advised to keep to the exact parts listed.

Dielectric and Capacity Losses Must be Kept to a Minimum

The first and principal requirement is that dielectric and capacity losses should have been reduced to an absolute minimum because small losses of this nature, which would pass unnoticed in a broadcast receiver, might quite conceivably cause utter failure of a set operating on 7 metres. Another point which should not be overlooked is that everything must be perfectly rigid. The reason for this requirement will be obvious when it is realised that all those components in the H.F. circuits act like plates of a condenser, so that any movement causes a change in capacity and so affects tuning. The capacity change for tiny movements is admittedly small, but is not by any means inappreciable when compared with the small tuning capacities employed.

Points about the Condensers

The minimum capacity of the tuning condensers must be as low as possible to ensure a high maximum to minimum ratio. The higher this ratio the greater the tuning range covered by any particular coil. Contact between the moving vanes and corresponding terminal must be perfect and invariable, whilst the contact between individual plates must be ensured by soldering them together. All the features mentioned are found on the instruments specified.

Tuning Control Must be Smooth

The importance of the tuning control can only be fully appreciated by those having experience of short-wave work. It must be perfectly smooth in action, and should have a substantial reduction drive, so that the vanes of the tuning condenser can be rotated at an almost infinitesimally low speed. A large operating knob is also a great advantage, and simplifies control in a remarkable way. Both tuning and reaction knobs of the components used by the writer are 2 inches in diameter, and are thus very convenient to operate.

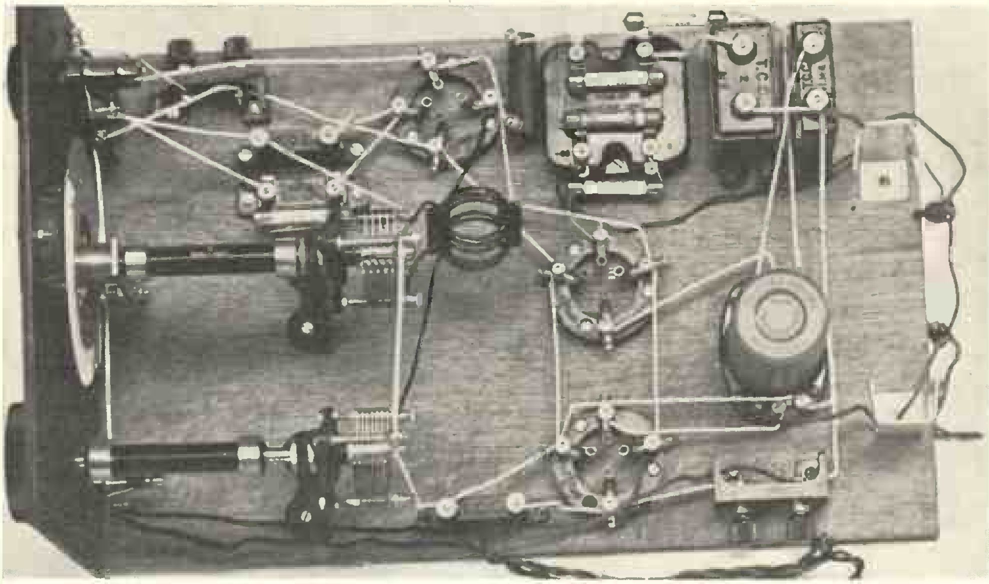


Fig. 5.—The Layout of the Components on the Baseboard.
Study this in conjunction with Fig. 2.

The Extension Spindles

Extension spindles between condensers and operating knobs greatly facilitate

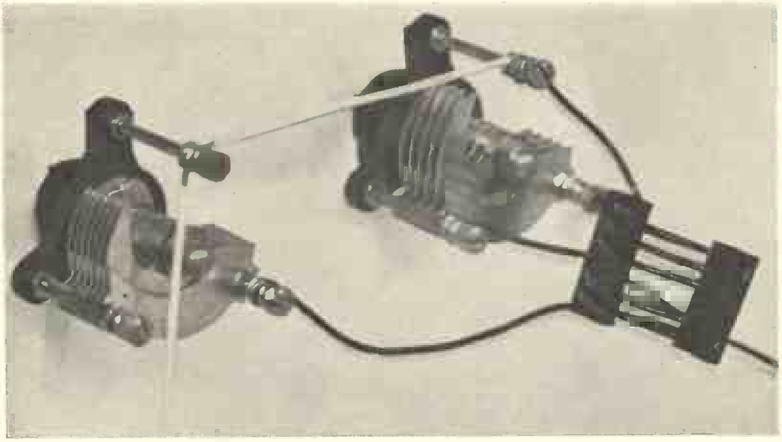


Fig. 6.—Enlarged View of the Tuning System.
The coil is supported by its own connecting leads.

control, since they minimise the possibility of hand - capacity effects. But the extensions must be dead rigid for the very slightest amount of back-lash would render the set practically unworkable.

Assembling the Parts

Before any assembly can be begun the panel must be drilled and made ready to receive the various components. Fig. 4 shows the disposition of the holes, and this should not be difficult to follow. The large opening for the dial escutcheon can best be made by boring a series of holes just inside the lines and then removing the wood by means of a gouge or knife, afterwards cleaning off the edges with a half-round file.

All the other holes can be made with a brace and suitable drills.

Mounting the Components

Next mount all the components as shown in the wiring plan ; the two resistances, H.F. choke and coil assembly are not secured to the base-board, but are held in place with the wiring, which should be as short and rigid as possible. The bush of the series aerial condenser is insulated from the plywood panel by means of two ebonite washers, which must be made or bought separately, as they are not supplied with the condenser.

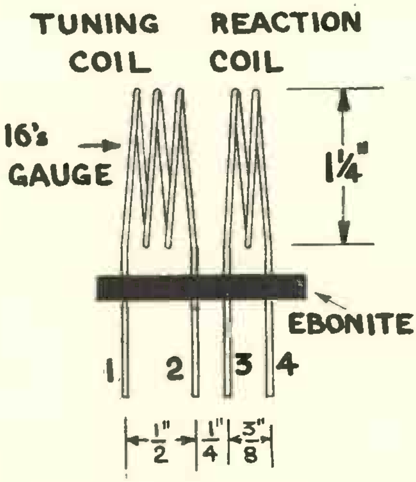


Fig. 7.—Details of the Coil.

The Wiring

The wiring is carried out principally in Glazite insulated wire, the battery leads being made in flex. All wires must be kept as short and rigid as possible, and should be arranged in the positions shown in Figs. 2 and 5. All connections but one (to one end of the 30,000 ohm de-coupling resistance) are made by securing the wires under the terminal nuts. The odd connection should be soldered, since the resistance connecting wire is not long enough to reach the terminal to which it is joined.

Connecting Up and Using

When completed, the set should be connected to aerial, earth, batteries, etc. In this respect it should be pointed out that best results are to be obtained from an aerial not more than 20 feet long, although a larger aerial can be used if desired.

With a recommended high tension voltage of 100, plug G.B. -1 should be put into the $1\frac{1}{2}$-volt socket, and G.B. -2 into the 7·5-volt socket of the grid bias battery.

The Headphones at First

When first trying out the set it is best

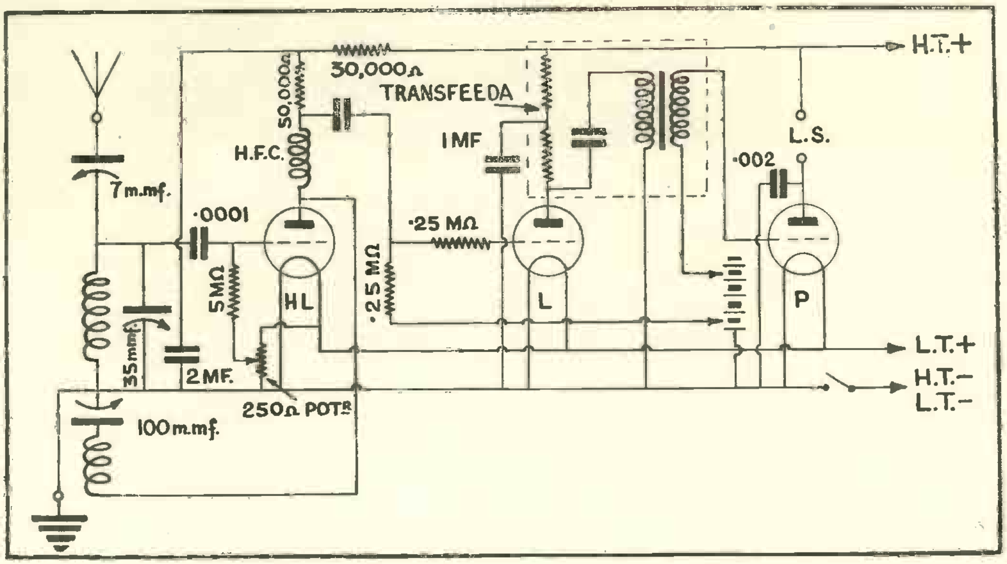


Fig. 8.—THE CIRCUIT DIAGRAM OF THE 7-METRE SET.

to use headphones, because tuning is so sharp that signals might be missed on a speaker.

Adjusting the Aerial Series Condenser

If a short aerial is in use, turn the aerial series condenser to its maximum capacity (plates parallel), but with a longer aerial a smaller capacity will be better.

Next set the tuning and reaction condensers to minimum (vanes entirely out of mesh). Turn the reaction knob very slowly until the set is just on the point of oscillation, as indicated by a breathing or faint rushing sound. Should a loud "plop" indicate that oscillation has set in suddenly, rotate the potentiometer knob until a point is reached at which oscillation starts gradually as reaction is slowly advanced.

Keep the Set Just Oscillating

Now rotate the tuning knob as slowly as possible, at the same time increasing reaction as necessary to keep the set just on the point of oscillation. The first signals to be heard will probably be in morse, and will readily be recognised as such by the "chirping" sound.

Telephony signals will also be heard as a whistle at first, but as the tuning dial is slowly rotated the whistle will just disappear and then come in again. Turn the dial to the "silent point" between the two whistles, and slack off reaction slowly until the speech or music becomes intelligible; this might also necessitate a slight alteration to the tuning condenser.

How to Overcome a "Dead Spot"

It might be found with some aerials that oscillation ceases at a certain point on the tuning dial, and cannot be created again, however far the reaction setting is increased. This is due to a "dead spot," which can be overcome by suitably adjusting the capacity of the series aerial condenser.

Effect of a very long Aerial

In some cases where a very long or high-capacity aerial is employed it might be necessary to remove the earth lead before oscillation can be obtained. Such a state of affairs points to the fact that a better aerial should be erected if possible, although the set can be used without an earth lead instead if desired. Naturally, results will not be so good as when efficient aerial and earth leads are employed.

Making a Range of Tuning Coils

For the benefit of those readers who prefer to make their own coil, and possibly some additional ones, for covering other wavelength ranges, a drawing is given to show all constructional details.

As will be evident from the drawing, there are two windings, one for tuning and the other for reaction. The tuned winding consists of three turns, and the reaction of two turns of 16's gauge enamelled wire, $1\frac{1}{4}$ inches in diameter. Both coils are made by winding the wire round a wooden cylinder about 1 inch diameter. Due to the springy nature of the wire, the turns uncoil slightly, and so increase in diameter.

How the Coils are Kept Rigid

They are kept rigid by passing the ends of each winding through tightly fitting holes made in a strip of ebonite, and the ends are used for connecting purposes.

The coil illustrated, like the ready-made one specified, will cover a tuning range of approximately 5 to 8 metres; the actual range depends to a certain extent on the aerial employed.

Coils for other ranges can be made in an identical manner by using a greater number of turns. For the sake of compactness the larger coils should be wound with the turns closer together, leaving the same space between the two windings.

Number of Turns for Different Tuning Ranges

As a guide, it might be stated that suitable numbers of turns for other tuning ranges are as follows:—

Average W/L.	Tuning Turns.	Reaction Turns.
12 metres .	4	3
20 metres .	6	4
40 metres .	11	8

Why Plug-in Coils are not Used

The reason that the coils are not made to plug into a holder, so as to simplify coil changing, is because such a scheme would involve longer wiring, and would introduce many losses which must be avoided at all costs. With the scheme employed, coil changing is rather laborious in contrast to the methods employed in receivers operating upon longer wavelengths, but it has the very strong advantage of "squeezing" the last ounce of efficiency from the set.

TWO PRACTICAL TIPS

ADJUSTING A REED SPEAKER

IT is a good plan occasionally to make sure that the reed or armature of simple type reed and balanced armature loud speakers is not fouling the poles on loud notes, or that loss of signal strength is not being experienced because it is too far apart so that the speaker fails to give its maximum output. A knob is generally provided for the purpose of adjustment and this should be turned while the set is working until a loud click is heard and the quality of reproduction becomes very tinny. This shows that the pole magnets are being touched and the knob should be turned back slowly until the quality of reproduction is satisfactory and no rattle is heard on loud notes. With some speakers a slotted terminal is provided instead of a knob, and this can be turned with a coin or a screwdriver.

HOW TO TELL WHETHER A SET IS OSCILLATING

A simple test to determine whether a receiver is in a state of oscillation is by wetting the tip of a finger and tapping the grid terminal of the detector valve. Listen carefully to the clicks that take place when this is done. If the set is oscillating a double click will be heard—one click when the terminal is touched and another when the finger is removed. If no click is heard when the finger is taken off, then the set is not oscillating.

CONSTRUCTION, CALIBRATION, AND USE OF THE WAVEMETER

By H. W. JOHNSON

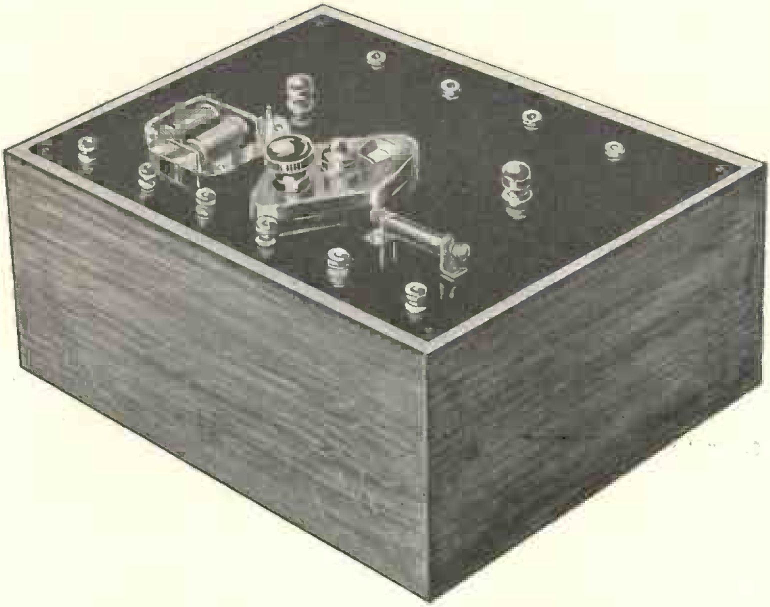


Fig. 1.—THE COMPLETED WAVEMETER.
For the sake of clearness the lid is not shown here.

THE wavemeter is an instrument which is used for detecting the presence and measuring the wavelength of high frequency currents, and it is therefore of great value to the radio engineer and wireless amateur.

There are various types of wavemeters ; all types have the same essential features, though they differ from each other in their component parts and constructional details.

This apparatus can, for instance, be used for calibrating the condenser scale of a radio receiver in terms of wavelength, or for adjusting and tuning up a radio receiver. Details for carrying out both these operations, together with other uses, are described in this article.

Essential Features of a Wavemeter

The essential features of a wavemeter are :—

(1) A calibrated circuit which is capable of receiving high-frequency currents produced by some distant transmitting station, and measuring their wavelength, or which will produce and transmit high-frequency currents of known wavelength.

(2) A source of power for exciting the calibrated circuit when the instrument is used for transmitting.

(3) A detector which will indicate when resonance is obtained in the calibrated circuit.

THE CALIBRATED CIRCUIT

The components of this circuit consist of low-resistance inductance units and a plate condenser with air dielectric. The condenser should be of the variable square law type, in order that the scale of wavelengths, to which it is calibrated, may be uniform, and therefore read with equal accuracy throughout the limits of the scale. The range of the instrument may be increased by introducing the inductance units in succession into the circuit. The maximum value of the condenser capacity is so arranged that when used with the initial inductance unit the resulting wavelength value on the condenser scale shall just exceed the wavelength determined by the combination of the minimum value of the condenser capacity and the next inductance unit, which is introduced into the circuit. The efficiency and accuracy of the instrument depends upon keeping the ohmic resistance of the inductance units and the condenser plate connections as low as possible, in order to reduce the resistance of the calibrated circuit to a minimum.

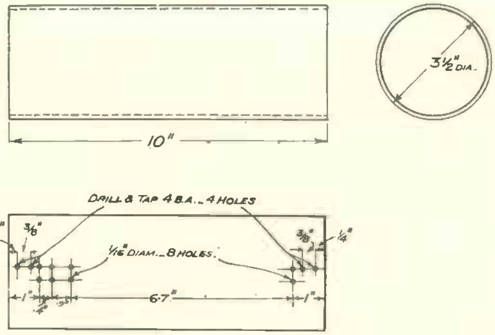


Fig. 2.—Details of the Ebonite Tube Former.

Four pairs of 1/16-inch diameter holes are drilled for the tappings and ends of the winding. Two pairs of holes are drilled and tapped 4 B.A. for the bracket fixing screws.

The Source of Power

A buzzer, which is operated by a suitable dry battery or accumulator, is perhaps the easiest and most convenient method of providing the power to excite the calibrated circuit with high-frequency currents. The currents so produced by the buzzer produce a series of trains of damped oscillations in the circuit which will radiate a series of trains of damped waves following each other at a frequency which is audible in the buzzer. The frequency, and therefore the wavelength, of the oscillations of each train is determined by the value of the inductance and capacity in the calibrated circuit, and may be obtained from the condenser setting on the scale.

When it is desired to produce a continuous train of oscillations, the calibrated circuit should be excited with the power obtained from a valve oscillator. The circuit will then radiate continuous waves of energy, similar to the carrier waves radiated from broadcasting stations, but considerably weaker in strength.

The Detector

The high-frequency current in the calibrated circuit may be detected in various ways. Two of the best detectors which are used are (1) A thermo-junction and sensitive galvanometer, and (2) Crystal and telephones.

The Thermo-junction and Sensitive Galvanometer Detector

A fine wire is included in the calibrated circuit and becomes heated by the passage of the received high-frequency currents through it. Welded to the centre of this fine wire is the junction of a thermo-couple composed of the alloys, constantin and manganin which, when heated by the fine wire, develops an E.M.F. The ends of the thermo-couple are connected to a sensitive galvanometer which gives a deflection, the value of which will depend on the magnitude of the E.M.F. developed by the thermo-couple. When resonance is obtained in the calibrated circuit the high-frequency current is at a maximum value, and consequently the gal-

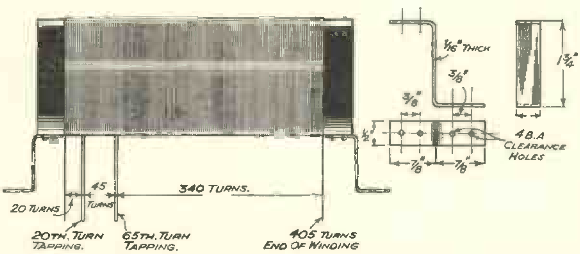


Fig. 3.—The Completed Winding on the Ebonite Tube Former.

A bracket is fixed to each end of the former with two 4 B.A. screws.

vanometer will then give its greatest deflection. Greater sensitivity of the detector is obtained by placing the fine wire and the thermo-couple in a glass bulb from which the air has been evacuated.

The Crystal and Telephone Detector

The crystal rectifies the received high-frequency current in the calibrated circuit. When resonance is obtained in the circuit the sound heard in the telephones will be a maximum. This detector, although simple and convenient to make up, is not so accurate as the thermo-couple and galvanometer, as it is difficult to gauge precisely the exact position on the condenser when the maximum sound is heard in the telephones. With the thermo-couple and galvanometer detector the resonant position of the condenser is clearly given when the highest deflection is obtained on the galvanometer. The crystal and telephone detector cannot be used to detect high-frequency currents in the circuit which are produced by continuous waves which are not modulated, because telephones will only respond to an audio frequency. In such cases beat methods of reception and detection, by using a heterodyne type of wavemeter, should be used.

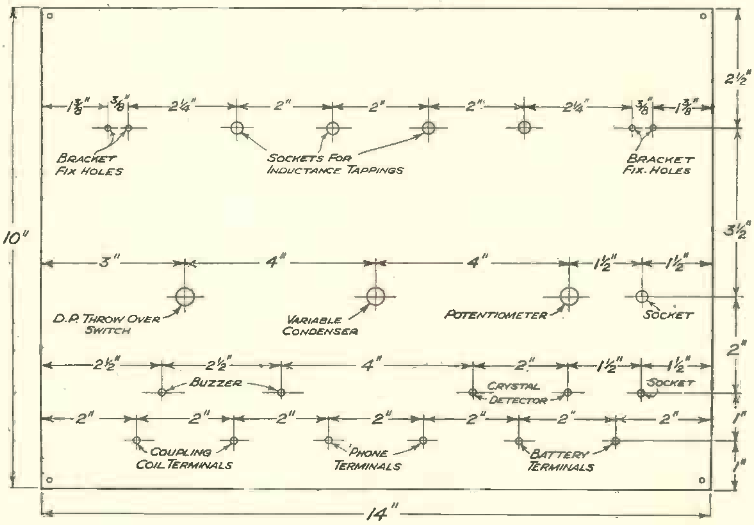


Fig. 4.—The Panel Drilling Diagram.

The dimensions given in the diagram may have to be varied slightly, depending upon the make of components which are used.

CONSTRUCTION OF A BUZZER TYPE WAVEMETER

Components and Materials Required

Three inductance units wound on an ebonite former.

One ·0003 microfarad variable air condenser of a good make (square law type, suitable for panel mounting).

One buzzer which will give a clear musical note when operated with two dry cells.

One crystal detector unit, preferably of the permanent adjustment type.

One D.P. change-over switch one hole fixing, of the sliding contact, or rotary type, and panel mounting.

One pair of sensitive headphones, 4,000 ohms resistance.

One potentiometer, 400 ohms resistance, one hole fixing and suitable for panel mounting.

Six banana type plugs and sockets, panel mounting.

Six ebonite-headed 4B.A. terminals.

One $\frac{3}{16}$-inch thick bakelite panel.

One $\frac{1}{2}$ lb. reel of No. 26 S.W.G. silk-covered wire.

Supply of glazite wire, insulated sleeving.

Preparing the Ebonite Former

A piece of $3\frac{1}{2}$-inch diameter ebonite tube is cut to a length of 10 inches and the ends squared. Mark off along the length of the tube two parallel lines $\frac{3}{16}$ inch apart, and at right angles to the squared ends. From one of the squared ends mark off on each of the lines distances of 1 inch, 1·4 inch, 2·3 inches and 9 inches, and drill a $\frac{1}{16}$-inch hole through the tube at each of the marked positions. Two holes, at distances at $\frac{1}{4}$ inch and $\frac{5}{8}$ inch from each end, and on one the marked lines should be drilled and tapped 4BA for the brackets which will hold the former to the panel.

Winding the Inductance Units

Mount the ebonite former in the lathe

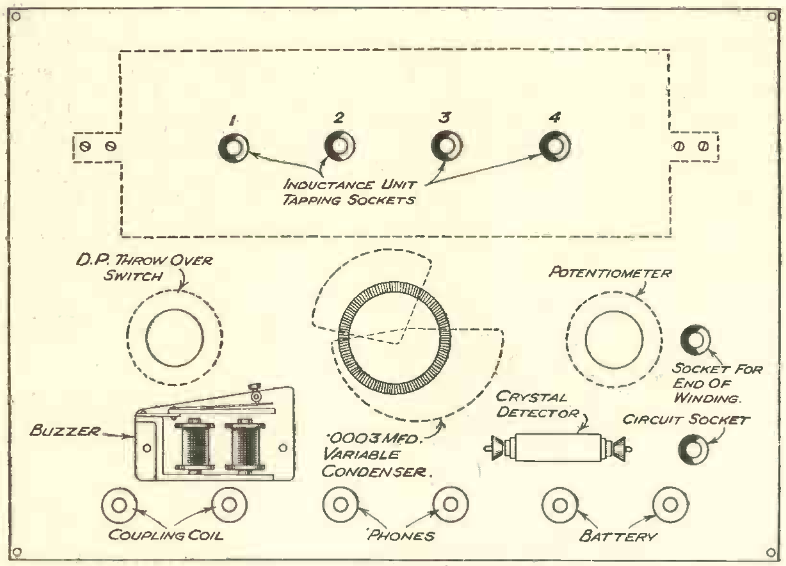


Fig. 5.—LAYOUT OF THE COMPONENTS ON THE PANEL FOR THE CONSTRUCTION OF THE WAVEMETER.

which should be geared down to its slowest speed, and thread 18 inches of the 26 S.W.G. single silk covered wire through a pair of holes nearest to the end of the former which is held in the lathe chuck. Carefully wind on the former twenty turns of the wire, keeping the turns close together and the winding even. This winding of twenty turns should occupy a length of 0·4 inch along the tube. Make the twentieth turn secure to the surface of the former with a binding of strong thread and take off a tapping 18 inches long of double wire. Thread this tapping through the second pair of holes, and continue the winding as before for another forty-five turns. Make off the forty-fifth turn and take off another tapping, threading it through the next pair of holes. The forty-five turns of wire between the first and second tapping should occupy a space of 0·9 inch. Continue the winding for another 340 turns, make off the last turn and cut off the wire to a length of 18 inches beyond the last turn and thread thus through the last pair of holes. The total length of the completed winding will be 8 inches. The bindings of strong thread are now removed.

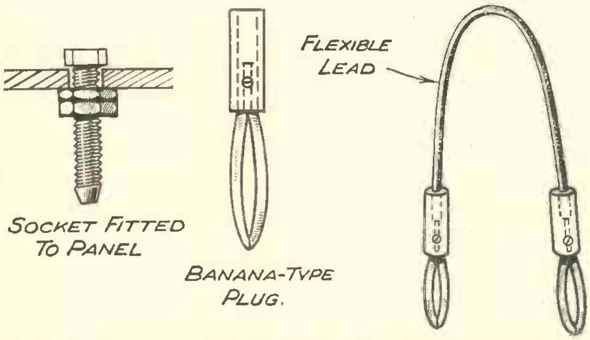


Fig. 6.—DETAILS OF PLUG CONNECTORS USED FOR CONNECTING THE INDUCTANCE UNITS TO THE CIRCUIT.

Three plug connectors, two with 4 inches of flexible, and one with 14 inches of flexible, are needed.

Marking Off and Drilling the Panel

Lay out the various components on the panel, allowing sufficient spacing between them to make a good and efficient job of the wiring. The exact spacing between the components will depend upon their make. The drilling centres for the fixing holes are measured off and marked on the panel. The layout of the components is indicated in Fig. 5. Drill through the panel at the marked centres with the correct size of twist drill. The panel should be placed flat on a piece of wood whilst drilling the holes.

Fixing Brackets to the Ebonite Former

A pair of brackets to the given dimensions are made from $\frac{1}{2}$-inch wide by $\frac{1}{16}$-inch thick brass, and the brackets are fixed to the holes which have been drilled and tapped in the ends of the former with four B.A. screws and nuts.

Mounting the Components on the Panel

Examine each of the various components and tighten any loose screws which hold the component parts together; test the D.P. change-over switch for making good contact in each position, and the variable condenser for absence of fouling between the moving and fixed vanes. Each component is now securely fixed to the panel, and lock-nuts should be fixed on all terminal studs and sockets. The zero of the condenser scale should be indicated when the moving vanes are completely away from the fixed.

Wiring the Components

From the diagram of connections and the layout of the components on the panel, measure and cut off to length the correct number of connections required. Glazite wire will be found efficient and will make a good, neat job. Washers should be placed between the bared wires and the fixing-nuts. The tappings from the inductance units should be cut off to the correct length and the bared ends connected directly to the socket terminals. A length of insulating sleeving should be drawn over the bared ends of each of the tappings and pushed up to the face of the winding before the connections to the socket terminals are made.

The Cabinet

A cabinet should be made in the form of a box, fitted with a hinged lid, which will be deep enough to allow for the components, which are mounted on the upper surface of the panel. The drawing indicates the design and principal dimensions, but in certain cases these dimensions may be varied depending upon the type of components which have been used. American whitewood will be quite satisfactory for the cabinet, and this wood is easy to work and may be stained and polished to any desired finish.

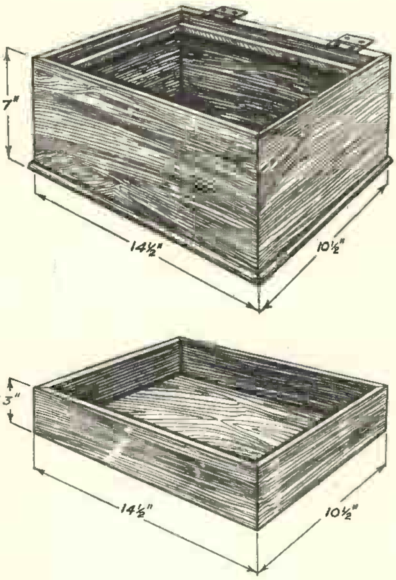


Fig. 7.—THE CABINET FOR THE WAVEMETER.

The box is made from $\frac{1}{4}$-inch thick planed American whitewood, which is stained and polished to the desired shade.

The lid is specially deep to accommodate the surface components on the panel, and is also made from $\frac{1}{4}$-inch thick planed American whitewood, stained and polished to the desired shade.

TESTING THE WAVEMETER

Short circuit the coupling coil terminals on the wavemeter panel and connect a two-cell battery to the battery terminals. Plug in one of the inductance units and switch on the buzzer at the D.P. change-over switch. The make-and-break contact screw of the buzzer should be adjusted to give smooth and regular vibration of the armature and emission of a clear note.

The Coupling Coil

Wind a coupling coil, consisting of three turns of No. 16 S.W.G. D.C.C. wire, 4 inches in diameter, and place it in a vertical position near the base of the aerial of a receiving set. Connect the ends of the coupling coil to the coupling terminals on the wavemeter, having previously removed the short circuit from these terminals. Arrange the value of the inductance unit and the condenser setting of the wavemeter, so that the wavelength of the transmitted energy from the wavemeter will be within the range of the receiving set whose aerial circuit is loosely coupled to the coupling coil of the wavemeter.

The Buzzer Note

Listen on the headphones of the receiving set and adjust the tuning of the set until the buzzer note is heard, which will indicate that the wavemeter will function as a transmitter. Switch over the D.P. change-over switch on the wavemeter from the buzzer to the crystal detector circuit and connect a pair of headphones in the circuit. When the local broadcasting station is transmitting adjust the wavemeter condenser, with a suitable inductance unit in the circuit, until clear reception is obtained in the phones; this will indicate that the wavemeter will function as a receiver; the potentiometer should be adjusted to increase the sensitivity of the crystal detector.

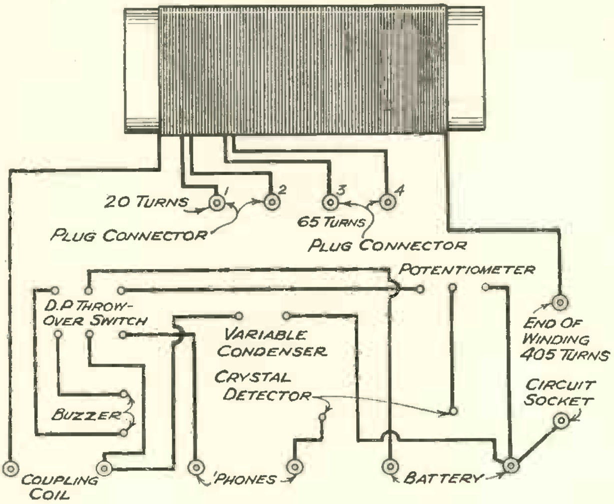


Fig. 8.—WIRING DIAGRAM OF THE WAVEMETER.

Glazite wiring is used for the connections. The inductance units are connected into the circuit with a banana-plug connector to the circuit socket.

Range to 250 metres :	Socket 1 connected to circuit socket.
Range to 600 metres :	Socket 1 connected to Socket 2 and Socket 3 connected to circuit socket.
Range to 2,200 metres :	Socket 1 connected to Socket 2 ; Socket 3 connected to Socket 4 ; and end of winding socket connected to circuit socket.

CALIBRATING THE WAVEMETER

There are various methods of calibrating the wavemeter, such as: (1) Comparison with a standard wavemeter; (2) Comparison with a receiving set whose condenser settings are calibrated in terms of wavelength ; and (3) reception of signals from various transmitting stations whose wavelengths are known.

Using a Standard Wavemeter

To calibrate the wavemeter by comparison with a standard buzzer wavemeter, fix the coupling coil close to the standard wavemeter which is excited and will radiate waves of known wavelength. The wavemeter to be calibrated is tuned to resonance by adjusting the variable condenser so that the maximum sound of the buzzer of the standard wavemeter is heard in the phones. Now gradually move the coupling coil away from the standard wavemeter until the sound of the buzzer is just audible and the slightest movement of the variable condenser causes the sound to cease. The condenser setting is read off on the scale, also the wavelength of the transmitted energy from the standard wavemeter from its condenser scale. The wavelength is now varied and again resonance is obtained on the wavemeter to be calibrated. noting the readings of the pointer on each of the condensers.

Plotting a Graph

A graph is plotted between the known wavelengths of the standard wavemeter, and the readings of the condenser pointer of the wavemeter to be calibrated, and from the graph, intermediate values of wavelength in terms of the reading of the variable condenser setting, may be obtained. The whole range of inductance units are added in turn to the circuit during the process of calibration, and graphs plotted for the ranges of 250 metres, 600 metres and 2,200 metres.

Using a Calibrated Radio Receiver

The calibration of the wavemeter by comparison with a radio receiver which is calibrated is performed by placing the coupling coil of the wavemeter near the base of the receiver aerial, switching on the buzzer, and tuning the receiver to resonance with the transmitted waves from the wavemeter. Note the condenser setting on the wavemeter, and the wavelength of the received energy on the receiver which is read off on the calibrated scale of the receiver condenser. The inductance units are in turn added to the wavemeter circuit until the complete range of the wavemeter is calibrated. Graphs are plotted between the wavemeter condenser readings and the known wavelengths indicated on the receiver condenser.

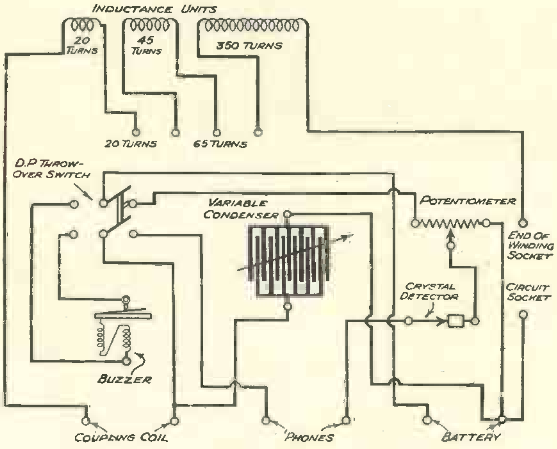


Fig. 9.—DIAGRAMMATIC SKETCH OF THE INTERNAL CONNECTIONS OF THE WAVEMETER.

The Most Accurate Method

The third method of calibration is dependent upon the transmissions from various broadcasting stations, and is therefore not quite so convenient as the previously mentioned methods, but it has the advantage of being accurate if carefully performed. The tuning notes from various broadcasting stations are tuned in on the wavemeter phones, and the condenser settings on the wavemeter corresponding to the known wavelengths of the energy received are noted. An aerial is not used.

USES OF THE WAVEMETER

Calibrating the Condenser Scale of a Radio Receiver in Terms of Wavelength

The coupling coil of the wave-meter is fixed in close proximity to the receiver aerial and the buzzer switched on. Adjust the position of the wavemeter condenser to the desired wavelength and tune in the receiver until the maximum sound of the buzzer note is heard in the receiver headphones. Now gradually increase the distance between the coupling coil and the aerial until the sound of the buzzer is just audible. A movement of the condenser in either direction of its adjustment will cause the sound to cease if the receiver is in resonance with the transmitted energy from the wavemeter. The position of the pointer on the condenser scale is noted and corresponds to the wavelength indicated on the condenser scale of the wavemeter.

The wavelength of the energy from the wavemeter is now adjusted to another value and the receiver again tuned into resonance.

Adjusting a Radio Receiver

Cut out the amplifier circuits of the receiver, or, if this cannot conveniently be done, connect the headphones across the primary winding of the transformer in the anode circuit of the detector valve.

The aerial of the receiver is energised at a known wavelength from the wavemeter and the condenser scale of the receiver set to this wavelength.

Now adjust the high and low tension voltage until the clearest note of the wavemeter buzzer is heard. Do not allow oscillation to take place; this will be indicated by distortion.

Testing the H.F. Circuit

The phones are connected in the same manner as the previous test, and if sharply tuned signals are received the H.F. circuit is in good order. Failure to receive signals will indicate that some part of the H.F. circuit, or component, including the detector valve, is faulty.

SERVICING

THE H.M.V. 521 RADIOGRAMOPHONE

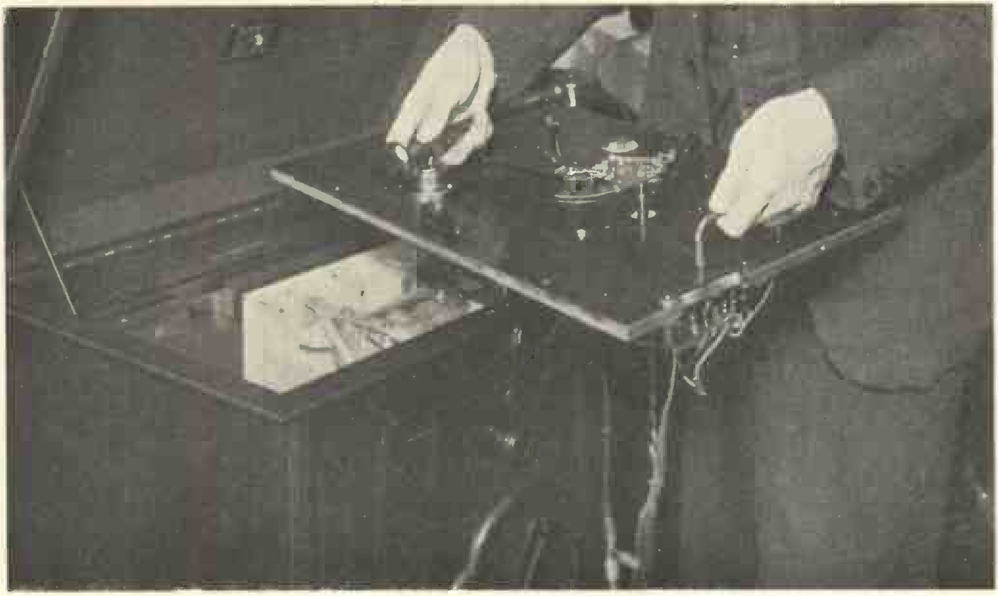


Fig. 1.—The Correct Way to lift out the Motor Board.

When dismantling this model, first remove the motor board. Now take out the cheese-head screw in knob extension piece and pull out the knob. The volume control, complete with bracket, can now be removed if the hexagon-head screw (fixing bracket) is removed. To take out the radio unit: (1) The motor board and volume control extension spindle must be taken out. (2) Remove 8 nuts (2 on each of the four bolts) on either side of chassis. (3) Remove mains aerial plug, together with any other attachments, and lift unit through top of cabinet.

Description of the Instrument

THE circuit consists of two high-frequency, screened-grid valves, one detector, one pentode output valve, permanent-magnet moving coil loud speaker, induction disc alternating current motor, and the "His Master's Voice" pick-up.

Technical Details of the Circuit

When these are being referred to look at Fig. 4, and you will see that the actual position of each component indicated in the theoretical diagram is shown in the pictures of the unit, so that they may be found in the least possible time without having to trace wiring unnecessarily.

HOW THE SWITCH WORKS

Off Position

The all mains current is disconnected from the valves and motor by the switch in the interior of the radio unit being "Open."

The Medium Wave (Radio) Position

The mains current is connected to the mains transformer by the switch in the unit being closed and "transformed" into the various voltages required to operate the set.

There are four separate voltages supplied from the windings of the mains transformer secondary:

(1) Four volts special alternating current supply for the filament of the U10 rectifier valve.

(2) Four volts alternating current supply for the "heaters" of the "indirectly heated" MS4 and MHL4 valves.

(3) Six volts special supply of alternating current for the filament of the PT625 pentode valve.

(4) 300 volts alternating current supply, which is turned into direct current by the U10 rectifier valve, passed through a "smoothing" system to "iron out" any ripple and passed to the anodes and screens of the valves at the positive supply.

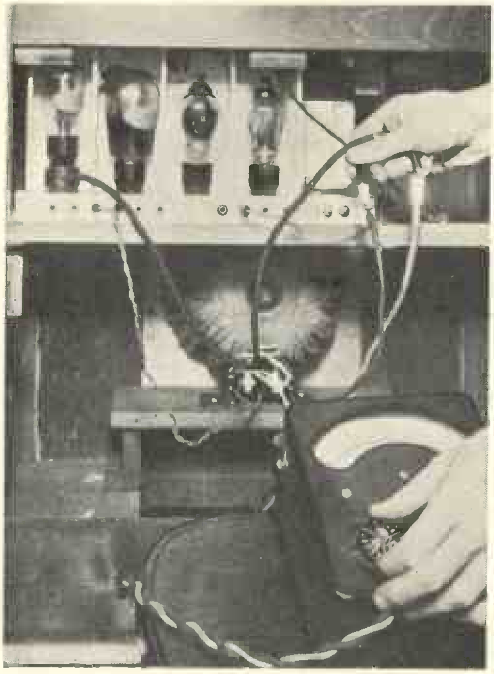


Fig. 2.—Testing the Emission of a Valve.

The "Gram" Position

In this position the switch leaves the mains current connected as before, but disconnects the tuning coils from the MHL4 detector valve and connects the blue wiring from the pick-up to the MHL4, at the same time altering the supply of H.T. current to the valve so that it now operates as a sound-amplifier valve instead of a radio detector valve.

USING EXTRA LOUD SPEAKERS

The instrument is capable of working two extra speakers of the low resistance, moving coil type, these being plugged into the pair of sockets marked "EXTRA LOUDSPEAKER VOL. CON."

Do Not Switch on the Instrument when no Loud Speaker is connected

When demonstrating an extra speaker, it is often desirable TEMPORARILY to disconnect the main speaker.

To do this, a switch must be connected in series with one of the speech coil leads clipped to speaker terminal strip. DO NOT OPEN THIS SWITCH UNLESS AN EXTRA SPEAKER IS CONNECTED,

The Long Wave Position

The switch in this position performs the operations described in the M.W. position, but also adds an additional tuning coil to each tuned circuit to enable it to tune to the long-wave band of wavelengths — Daventry 5XX, etc.

Fig. 3.—Testing the Output to the Loud Speaker.

OTHERWISE THE PENTODE VALVE MAY BE DAMAGED.

Moving iron or other high-resistance loud speakers may be used, providing that a special transformer is interposed between the EXTRA LOUD SPEAKER sockets and the high-resistance speakers.

ENGINEERING TEST NOTES

Should the results ON RADIO prove unsatisfactory, try the instrument on GRAM. In this way it may be possible to localise the fault.

Poor reproduction on both radio and gram would suggest that the fault lies between the grid of the detector valve and the loud speaker.

If reproduction on gram is good but radio is poor, the fault will in most cases be found preceding the detector valve.

Test the loud speaker by running leads from speech coil into an instrument which is known to be O.K.

Pick-up circuit can also be tested by connecting P.U. output into another instrument, or listening on earphones at the output of the pick-up.

Having eliminated P.U. circuit, loud speaker and motor as being cause of trouble, proceed to test the "H.T. feed," H.T. volts, Fil. volts and bias current on each valve and compare with the VALVE TABLE and the VALVE FAULT TABLE.

The tuned circuits associated with the grids of valves 1, 2 and 3 can be tested in the following manner: remove the two H.F. valves V1 and V2, and commence testing with only the detector and the pentode valves in position.

Connect the aerial lead to the grid socket (green wire) of the valve tester, or direct to the grid sockets of each H.F. valve.

Medium-strength signals should be obtained on both "long" and "medium" wave positions if detector and output stages are O.K.

The signals may be slightly distorted, and the tuning "flat," when the aerial is connected as specified.

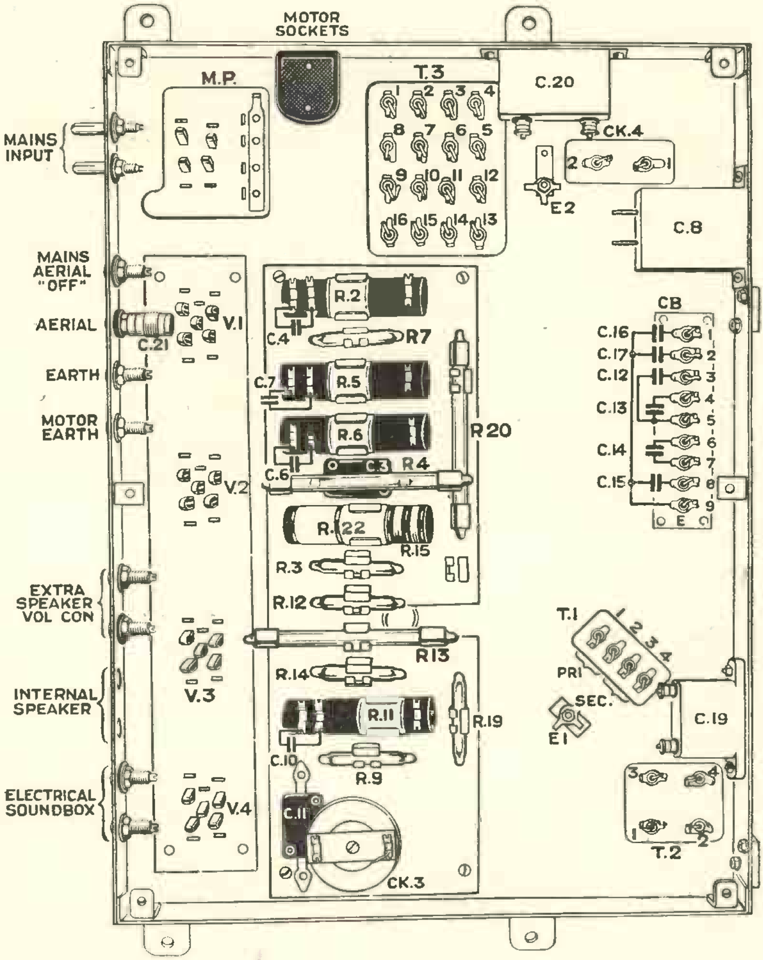


Fig. 4.—THE LAYOUT OF THE COMPONENTS OF THE H.M.V. 521 RADIO-GRAMOPHONE.

THE 521 H.M.V. FAULT LOCATION CHART

- **No radio. No gramophone.**
  - **Valves light** — *Note.* — No glow is visible from the PT625 or the U10 (two right-hand valves), but both should be warm.
    - Volume control set correctly ?
    - Tuning dial set correctly ?
    - Aerial correct ?
      - See that wire is not touching anything.
    - Earth correct ?
      - Lightning switch in good order and correctly set (test by bringing aerial lead straight to set).
    - Trace back carefully
      - See that there is no break—possibly concealed—in the wiring or plugs.
    - Examine plugs and leads carefully.
      - See that the plugs are not loose in sockets.
      - See that the electrical connection of the wire is correct inside the plugs.
    - Try new valves, especially U10, PT625, MHL4
      - All valves wear out, some more rapidly than others. Because a valve glows or is warm doesn't prove that it is still efficient.
    - Examine wires to loud speaker and plugs if fitted.
    - Voltage adjustment correct ?
      - Look at the electric supply meter or the marking on the light bulbs of the house.
    - Valves in correct positions check.
      - Compare position of voltage adjusting plug on radio unit with instruction book and markings on unit.
    - Valve pins making contact correctly with sockets ?
      - Clean with emery paper or scrape with a knife and wipe with dry cloth.
    - Tags in place on top of MS4 valves ?
      - See that the wires to the tops of these valves are firmly screwed up.
    - Disconnect any extension wiring there may be to see if the fault is there. A fault in the extension loud speaker wiring may have developed ; it is not always well laid, and frequently exposed to damage, especially in doors and windows.
  - **Valves do not light. Pilot light does not light.**
    - See that mains supply socket is O.K.
      - Check with voltmeter.
      - Or by inserting a suitable table lamp.
    - House switch is on ?
    - Plugs on supply cord O.K. internally ?
    - Supply cord is O.K. ?
    - House fuses O.K. ?
    - Set fuses O.K. (if fitted).
      - See that these are not "blown" or are not loose.
    - Motor supply socket at right of radio unit in position ?
      - Check with lamp with "set switch" in "gram" position.
    - Voltage adjustment screw loose ?
    - Plugs on supply cord loose on pins ?
      - Examine interior of plugs to see that electrical connection of wires is O.K.
    - Pilot lamp worn out or loose in socket.
    - Check voltage at radio unit.
      - Test supply plug with suitable lamp, this will tell you if the supply cord is O.K.

No gramophone. Radio O.K.	Motor revolves	–See that blue pick-up plugs at back of radio unit are in place. –Examine pick-up for damage, *i.e.*, needle jammed on one side or needle holder bent. –Is " radiogram " switch in " gram " position ? –Move volume control this way and that and inform service engineer if a fault is observable there so that he can bring another if necessary. –See that the needle is resting on the record correctly.
	Motor does not revolve.	–Examine motor for mechanical friction by turning turntable by hand. –If friction present see if the speed regulator arm on the motor has slipped off the speed regulator screw on the motor board. –See that all screws on the motor adjustment strip are tight and that adjusting links are present. –Check voltage adjustment of motor by instruction book and comparison with the voltage markings on the bulbs in the house. –See that the black motor plug on the right of the radio unit is in place and fitting firmly. –Examine all wiring to motor for damage, or looseness at plug or motor screws.
Faulty radio, gramophone O.K.		–Examine aerial and earth as under " No radio." –Try new MS4 valves. –See that tags on top of valves are firmly in position. –Examine all wiring and plugs connected with aerial and earth as under " No radio."

If detector and output stages are O.K., proceed to test V.2 (2nd H.F. amplifier stage) in the manner specified for detector valve, and then test V.1 (1st H.F. amplifier).

ENGINEERING HINTS ON CHECKING UP VALVE VOLTAGES AND CURRENTS

Valve.	Observations.
U.10 Rectifier	WITH INSTRUMENT SWITCHED OFF AND MAINS DISCONNECTED, measure resistance between plate and grid sockets, which should be 1,200 ohms (approx.) Resistance between grid or plate socket and earth should be approx. 600 ohms. A correct reading here shows that correct A.C. volts are reaching the valve, providing that current is reaching instrument and that resistance of primary T.3 is correct (lugs 1, 2, 3, 4 or 5). If incorrect check wiring from valve sockets to T.3. NO FILAMENT VOLTS.—Check wiring to lugs 9 and 10. LOW MILLIAMP READING.—Suspect valve; its emission may be low. Even though readings may be correct on pentode, a disconnection may have occurred between output transformer and speaker terminals. Check continuity from speaker output sockets to (2·1) on T.2 (pink wires).
M.S.4 V.2	ABSENCE OF FILAMENT VOLTS.—Check filament circuit (brown wires) from 11, 13 on mains transformer T.3. ABSENCE OF ANODE VOLTS.—Suspect U.10, break in circuit between filament of U.10 and tag 1 of C16, or C16 or C17 shorting to earth. A breakdown in resistance R3, choke CK2 or CK4 would also account for no plate volts. HIGH PLATE VOLTS AND NO CURRENT.—Suspect grid bias resistance, R6 faulty. LACK OF SCREEN VOLTS.—Suspect R5, R7. R20 disconnected, or C4 or C7 or C8 down to earth. NOTE.—With valve removed and instrument switched on, screen voltage between anode *socket* and frame (E) of unit should be 70 volts. Anode volts (anode tag to frame) should read 230V. Measure on " Avo " 1,200V scale.

ENGINEERING TABLE OF VALVES

Where a variation is shown in readings, the maximum reading is when the volume control is turned full on. All readings taken with valves in position and set switched on. With a His Master's Voice adaptor the measurements are taken at the valve holder sockets with the valves out. The voltage will be higher but there will be no grid bias reading. Filament volts must be measured with an A.C. voltmeter. All readings taken on Avometer Scale are "indicated," and NOT "actual." The Avometer Scale used is given to ensure that helpful measurements will be secured as the use of other scales or inferior meters will give different and possibly misleading readings.

Valves.	Location.	Appearance.	Temperature.	Function.	Anode Feed D.C. m.a.	Avo Scale.	Anode Frame Volts D.C.	Avo Scale.	Screen Feed Milliamps. D.C.	Avo Scale.	Screen Frame Volts D.C.	Avo Scale.	G.B. Volts.	Avo Scale.	Fil. or Heater Volts.	Notes.
U.10	Extreme right hand	No glow	Warm	Rectifier	17 m.a each anode	0·12	—	—	—	—	—	—	—	—	Approx. 4	*Do not* attempt to measure heater volts, anode to frame volts or grid to frame volts.
MS.4 (V.1)	Second from right	Glow	Warm	1st S.G. H.F.	0·2 to 2·5	0·012	Full volume 180 vol. con. at min. 230	1200	0·1 to 0·8	·012	0 to 60	1200	1·0 to 1·75	12	Approx. 4	—
MS.4 (V.2)	Third from left.	Glow	Warm	2nd S.G. H.F.	0 to 3·0	0·012	Full volume vol. con. at min. 240	1200	0 to 1·0	·012	0 to 80	1200	1·0 to 1·6	12	Approx. 4	—
PT.625 (V.3)	Second from left	No glow	Hot	Output (Pentode)	17	0·12	320	1200	Screen lead to valve leg must be broken to ascertain this feed.		210	1200	4·2	12	Approx. 6	Measure bias between grid and filament.
MHL.4	Extreme left from back	Slight glow	Warm	Detector	Full volume 2·8 vol. con. at min. 3·6	0·012	95	1200	—	—	—	—	0·5	12	Approx. 4	

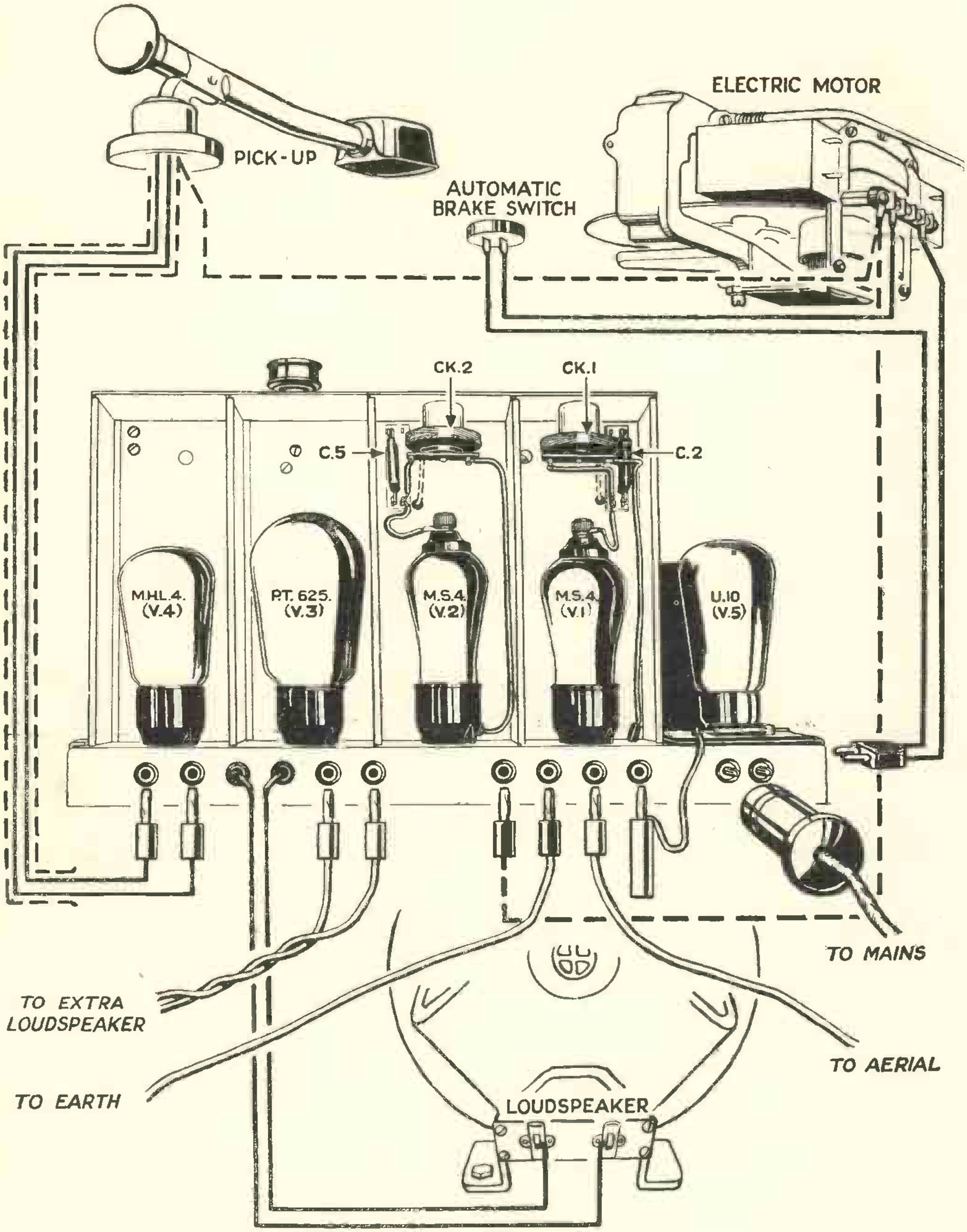


Fig. 5.—THE EXTERNAL CONNECTIONS TO THE H.M.V. 521 RADIOGRAMOPHONE.

This shows the respective positions of the valves, and shows where the various sockets, etc., are connected.

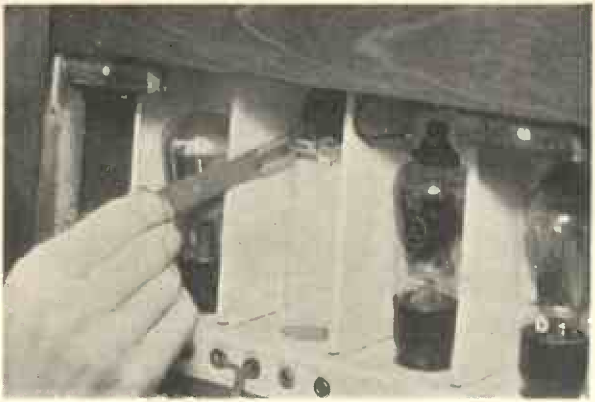


Fig. 6.—Replacing the Scale Lamp.

Engineering Hints—*continued*.

Valve.	Observations.
M.S.4 V.1	Test as previous M.S.4. Note.—In this valve *screen current* is fed *viâ* R.2 instead of R.5. Anode current passes *viâ* CK.1 instead of CK.2.
P.T.625 V.3	Screen is connected to pin normally used as cathode. Lack of Anode Volts.—Suspect faulty wiring between plate and CK.4 (yellow and red wires) or " dis " in primary of T.2 (lugs 3 and 4).
P.T.625 V.3 (*Contd.*)	Low Screen Volts may be caused by condenser C.12 or C.13 partially shorting to earth. Low Anode Volts would be caused by condensers C.16 and C.17 being broken down to frame, or CK.4 or primary T.2 partially shorted to earth. No Screen Volts.—Suspect resistance R.14 or C.13 shorting to earth. Anode Volts Low, Milliamps High.—Suspect open grid circuit; trace continuity from grid *viâ* secondary T.1 (lugs 3 and 4) to earth. Also check resistances R.15 and R.22 and make sure that C.15 is not short-circuited to earth. Anode Volts High, Milliamps Low.—Suspect valve—same may be old and down in emission. Note.—With valve removed and instrument switched on, the voltage between anode socket and frame (E) of unit should be 320 volts. Voltage between screen and frame (E) should be approx. 300 volts.
MHL.4 V.4	No Anode Volts.—Suspect faulty CK.3, C.14, C.11, R.13 feed resistance or R.12, C.12, C.16, C.17, CK.4 may be shorting to earth or winding of CK.4 may be " dis."

HOW TO CHECK THE COILS AND SWITCH CONTACTS

This can be done without removing unit. Set " Avo " to 1,000 ohm scale. Electrical Values ± 10 per cent.

Coil.	Switch set for.	Resistance.	
L.7	" M.W."	2·25 ohms	Measured between terminal point of Green wire on VC.1 and frame of unit. The resistance of the Long Wave coil is therefore 12·75 ohms.
L.7 and L.2	" L.W."	15 ohms	
L.8	" M.W."	2·25 ohms	Measured between terminal point of Green wire on VC.2 and frame of unit. Resistance of Long Wave coil is therefore 12·75 ohms.
L.8 and L.4	" L.W."	15 ohms	
L.9	" M.W."	2·25 ohms	Measured between terminal point of Green wire on VC.3 and frame of unit. Resistance of Long Wave coil is 12·75 ohms.
L.9 and L.6	" L.W."	15 ohms	
CK.1	—	85 ohms	Measure across ends. There is no need to disconnect wires from these chokes, as one side is isolated by condenser and valve anode.
CK.2	—	85 ohms	
CK.3	—	85 ohms	

ENGINEERING HINTS—*continued.*

Valve.	Observations.
MHL.4 V.4 (*Contd.*)	LOW ANODE VOLTS, if not accompanied by high milliamp. reading, may be due to any of the above components being partially shorted to earth (frame). LOW ANODE VOLTS, MILLIAMPS HIGH.—Suspect break in grid circuit. Check for continuity from grid *viâ* switch S.3 to condenser C.9, resistance R.10 or, with switch in "Gram" position, to centre contact, volume control VR.2, R.10 or R.11 may be faulty, and if disconnected would cause "open grid." Suspect also C.10—same may be shorting to earth. VERY LOW MILLIAMP READING WITH H.T. VOLTS HIGH.—Suspect R.11 and trace circuit from cathode of MHL.4 to earth. Low milliamp reading with plate volts NORMAL or slightly high denotes aged valve, down in emission. NOTE.—With valve removed and instrument switched on, the voltage between anode *socket* and frame (E) of unit should be 215 volts.

COLOUR WIRING CODE

The instrument is wired according to a colour wiring system which will be found of the utmost value in tracing circuits.

Black . .	True Earth Circuit.
White . .	Cathodes when not at Earth Potential.
Red . .	High Tension D.C. Circuit.
Yellow . .	Anode Circuit.
Green . .	Grid Circuit.
Brown . .	Filaments.
Blue . .	Pick-up Circuit.
Light Blue .	Pick-up Circuit Low Potential Side.
Pink . .	L.S. Output after condenser or transformer.
Violet . .	Aerial Circuit.
Orange . .	Mains.
Yellow (Red Tracer) .	Screen Grid Circuit.
Yellow (Black Tracer).	Pentode (Screen Grid Circuit.)
Grey . .	Used for leads not falling within the usual Colour Code.

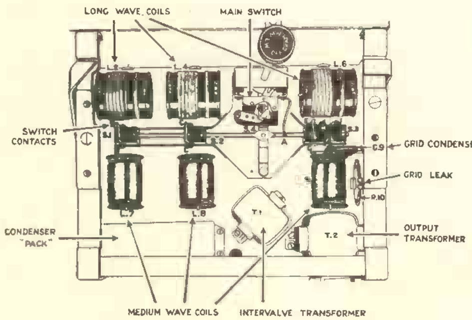


Fig. 8.—DETAILS OF THE COILS.

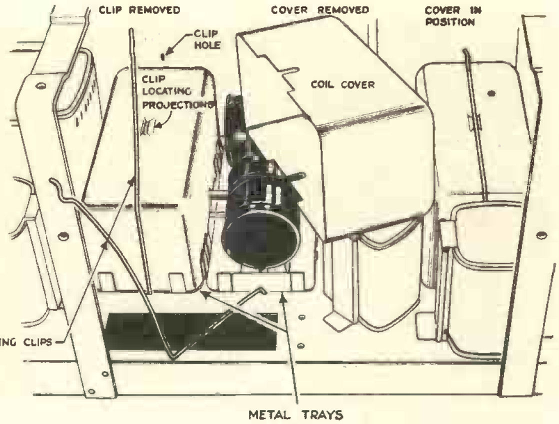


Fig. 7.—HOW THE COIL COVERS ARE REMOVED.

RESISTANCES OF COMPONENTS

A.—Switch off the set.

B.—Take out the valves and pilot lamp.

Always isolate the component you wish to test by removing at least one wire or you may get a fake reading.

COMPONENT.	RESISTANCE (± 10 %).
CK.4 L.F. choke (measure across tags without detaching wires) .	750 ohms.
Intervalve Transformer (T.1)—	
Primary (tags 1 and 2)	1,000 ohms.
Secondary (tags 3 and 4)	10,000 ohms.
Output transformer (T.2)—	
Primary (tags 3 and 4)	1,000 ohms.
Secondary (tags 1 and 2)	1 ohm.
Disconnect loud speaker.	

SERVICE TABLE

Before testing instrument on Radio, first obtain satisfactory operation on Gramophone to ascertain that amplifying stages are O.K.

Symptoms.	Possible Cause.	Action to be taken.
No reproduction. Low-pitched hum. High ma. reading on pentode.	Lack of bias on P.T. 625	Test R.15, R.22 for resistance, and C.15 for breakdown to earth.
Slight loss of volume and rise in ma. reading—detector anode.	No bias on MHL.4.	Test R.11 for resistance and C.10 for breakdown to earth.
Great loss of volume on radio only. Lack of reaction. High ma. reading on MS.4 anodes.	No bias on MS.4's.	Test R.6 and C.6 as above.
Low-pitched hum. No loss of volume.	Lack of smoothing.	Test C.20 for breakdown. Replace if necessary.
Bad crackling.	Bad contacts. Suspect volume control.	Also see Test Tables.
Howling of a particular pitch.	MHL.4 microphonic.	Place elastic band round glass and pack with cotton wool, or replace valve.
Gradual loss of volume, accompanied with distortion.	U.10 loss of emission.	Replace. If no improvement, trace from ma. and volt readings as from valve table.

Trouble.	Suggested Action.
Pilot lamp beneath tuning scale does not light when instrument is switched on. NOTE. — If valves glow when gramo-radio switch is turned to gramophone, mains are reaching the instrument.	Make sure that supply is reaching the instrument; test by means of a lamp connected across the two sockets at the end of the mains connecting flex. If current is reaching the instrument, the pilot lamp bulb is probably loose in holder. Lamp holder is attached to side of PT.625 valve compartment. Check these points, and if bulb is faulty, replace with 6-volt bulb.
Motor runs sluggishly and slows up on heavy passages.	See that mains voltage adjusting screw is in its correct position. Allow motor to run idle for a few minutes, the lubricant may have become sticky. See that there is no mechanical friction.
Threshold noise on manipulating volume control on radio when near oscillation point.	To cure this try changing over or replacing MS.4 valves.
Hum.	Check earth connections, reverse mains plug, change U.10 rectifier valve and change MHL.4 valve.
Uncontrollable reaction and oscillation on radio.	Examine leads to volume control for disconnection.
Faint signals and failure of reaction on certain parts or whole of scale.	Possible damage to H.F. chokes in MS.4 valve compartments due to insertion or removal of valves.
Premature oscillation at low position of volume control.	Possible damage to H.F. chokes in MS.4 valve compartments due to insertion or removal of valves.
Lack of selectivity, or double tuning points on powerful nearby transmitter.	When within 20 miles of a high-power station, reduce aerial to about 15 feet in length. Use a short earth connection.

Fig. 9.—Extracting the Pick-up Head of an H.M.V. Radio-Gramophone.

To take the pick-up to bits (1) remove the screws holding the metal cover and remove the knurled needle-screw. The pick-up head is secured by a small screw on the underside of the arm. When this is removed the head may be withdrawn. (2) Carefully lift off horseshoe magnet and place on a suitable iron or steel "keeper." (3) Unscrew metal charging plate. (4) Carefully remove rubber damping sheet.

To take the coil out (1) unscrew hexagonal bolts securing the solid pole pieces. (2) slide coil out of pole pieces.

Resistances of Components—*continued*.

Component.	Resistance (± 10%).
Mains Transformer (T.3)—	
Primary sockets—	
Sections—	
1 to 2 . .	18 ohms.
2 to 3 . .	27 ohms.
3 to 4 . .	6·5 ohms.
4 to 5 . .	6·5 ohms.
Continuity—	
1 to 3 . .	45 ohms.
1 to 4 . .	51·5 ohms.
1 to 5 . .	58 ohms.
Secondary lugs (valves and lamp out)—	
Valve heater and pilot lamp winding—	(approx.)
Lugs 11 to 13 . (valves and pilot lamp out)	0·1 ohm.
Filament winding (PT.625)— (lugs 14 to 16) (valve out)	0·5 ohm.
Rectifier valve filament winding— (lugs 9 and 10) (valve out)	0·1 ohm.
High voltage winding (centre tapped at lug 7 to E)—	
Lugs 6 to 8 . .	1,050 ohms.
Lugs 6 to 7 . .	470 ohms.
Lugs 7 to 8 . .	580 ohms.

The D.C. resistance difference between the two halves of the secondary winding of T.3 (110 ohms) is due to the larger amount of wire on one half of winding.

THE 521 PICK-UP

WHAT IT IS, AND HOW IT WORKS

How the Pick-up Works

The electrical pick-up is really a small dynamo, inasmuch as it consists of a powerful magnet and a coil of wire.

In the dynamo the coil of wire rotates between the poles of the magnet ; in the case of the pick-up, however, part of the magnetic system consists of a pivoted piece of iron to which is attached the needle, which is operated by the movement of the needle in the groove of the record.

The movement of this iron "armature," which extends through the centre of the coil, and links (magnetically) the strong permanent magnet, has the effect of varying the magnetic field in which the coil is lying, thus achieving the object of the dynamo, in which case, however, the coil is turned through the magnetic field to get the same variation.

The pick-up therefore consists essentially of three parts, a magnet, a coil of wire and a pivoted moving iron armature, to the end of which is connected the needle. The movement of the pivoted

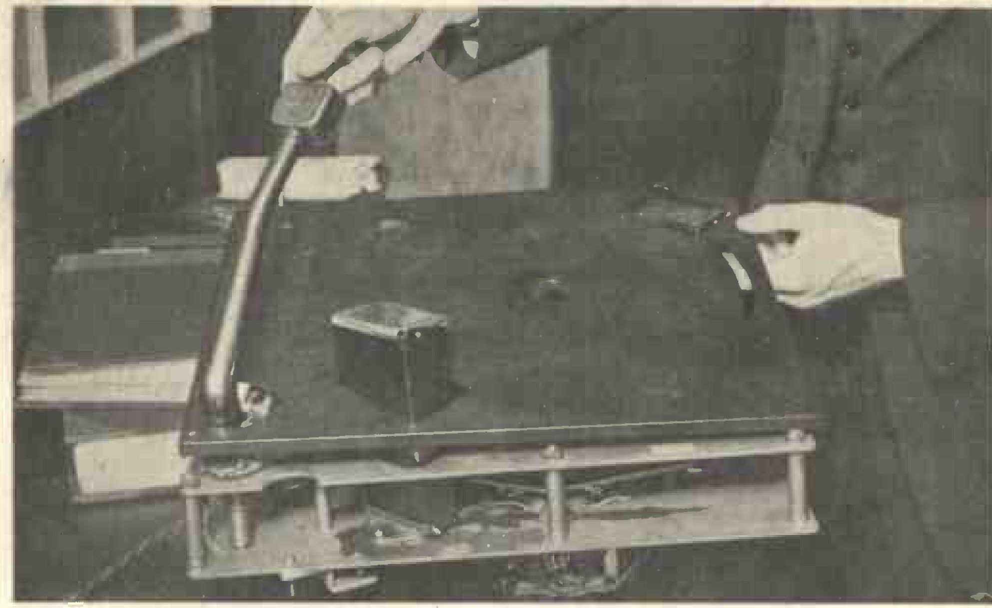


Fig. 10.—Taking Top Plate of Automatic off an H.M.V. Automatic Mechanism.

armature by causing a varying magnetic field to circulate round the coil, induces in the coil an electrical current which varies in sympathy with the movement of the needle. The movement of the needle, therefore, sets up an electric current in the coil in sympathy with the shape of the grooves in the gramophone record, producing, as it were, an electrical reproduction of those grooves in the form of a varying current, which can be applied to operate an amplifier for reproduction through a loud speaker.

The electrical output of the pick-up on the Model 521 varies between about 1 and 5 volts, and the output will be less on soft passages and more on loud passages, since on loud passages the needle moves to a greater degree.

What to do if the Pick-up appears Wrong

If anything should go wrong with the pick-up, refer at once to the Fault Finding Table on page 250, but before you attempt to take the pick-up to bits make sure that the trouble is really there by trying out the set on radio. If the trouble is experienced on radio *also*, it is quite likely that it is not in the pick-up at all, but that possibly new valves are required, or the loud speaker needs adjustment.

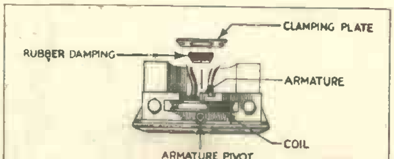


Fig. 11.—Diagram showing Parts of the Pick-up.

How to Test the Pick-up

Whether or not the pick-up is working correctly may be tested quickly as follows :—

Disconnect the wires from the pick-up to the instrument, and connect a pair of 4,000-ohm head telephones across them, place the pick-up in the playing position on a revolving record, when signals of moderate crystal strength should be heard clearly. This will indicate that the pick-up is giving its correct electrical output.

If there is no output at all, or some other mysterious fault, look at the Fault Finding Table, which will tell you practically anything which can possibly go wrong with this electrical pick-up, and what to do.

Look Out for Dust

The chief thing which may be found is that some dust has become lodged between the needle and the armature or magnet, causing a rattle.

This article on "Servicing H.M.V. Receivers" is continued in Part 6. Ready October 21st. Order your copy to-day.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8-11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

MAKING A VALVE AND SET TESTER

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

GANGED COIL CIRCUITS

etc., etc.

1/-

Part 6

IN ABOUT 24 WEEKLY PARTS

Fig. 12.—TESTING THE OUTPUT OF THE PICK-UP.

The headphones are attached to the two blue pick-up plugs. If the output is excessive, the air gaps are probably too small. Low output probably means: (1) gaps too large; (2) weak magnet; or (3) damaged armature.

It is surprising how a permanent magnet will pick up small particles of metal in places where one would least expect to find them, but it will be found that these can be cleaned away satisfactorily with the use of ordinary plasticine, which, while not being liquid or greasy, picks up any little particles of dust from the gap and collects them without causing them to fly to other parts of the pick-up. The use of plasticine for removing small specks of dust is a tip well worth remembering.

Do not take the pick-up to bits until you have satisfied yourself that it is wrong. The first thing you should do is to test the output of the pick-up with the head telephones, and then if you find that you have to take it to pieces, *very carefully* follow the directions given, because, if the pick-up is reassembled incorrectly, you may have a great deal of trouble in getting it to go right, especially with regard to the "damping" arrangements.

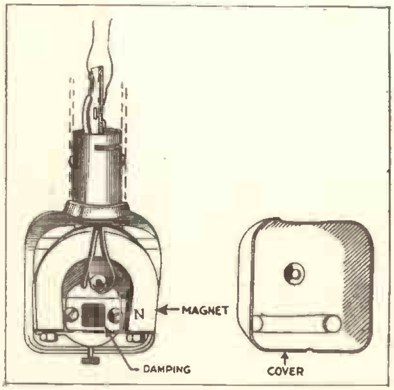


Fig. 13.—HOW THE PICK-UP HEAD IS REMOVED FOR EXAMINATION.

This "damping" consists of a sheet of rubber, which prevents the little metal armature from flopping on to either of the two magnet poles, and prevents the armature striking the magnet pole on very loud passages, or if the pick-up is accidentally dropped, jamming over on one side.

Electrical Details

Direct current resistance, 6,000 ohms.

Alternating Current impedance, 37,000 ohms at 800 cycles per second.

Output in volts: from 1 to 5 volts on loud passages.

The Parts of the Pick-up (Fig. 11)

The pick-up consists essentially of:—

(1) Horse-shoe magnet, to provide the magnetic field.

(2) Pole pieces, which transmit the magnetic field to the coil and armature.

Fig. 14.—ADJUSTING POSITION OF NEEDLE DROP ON "HIS MASTER'S VOICE" AUTOMATIC RECORD CHANGING MECHANISM.

This will be fully dealt with in a later section covering all the servicing details relating to the automatic record changing mechanism.

FAULT FINDING TABLE FOR PICK-UP

(Make sure that the instrument is O.K. on radio.)

Symptom.	Suggested Cause and Action.
Buzz or rattle heard in the loud speaker,	Iron filings or dust between the armature and pole pieces. Remove pick-up cover and top damping sheet and carefully examine for iron filings or dust, if necessary removing them with a thin strip of *plasticine*, carefully inserted between the armature and the pick-up pole pieces. Special attention is paid to any dust which may be on the underside of the flat portion of the armature. Be careful to remove all traces of plasticine.
No output from pick-up or low output from pick-up.	Examine the pick-up to see whether or not the armature or reed has been jammed on one side or other of the poles. Examine for perished rubbers on the armature spindles. Carefully slacken the hexagonal nuts slightly, and by exerting pressure tending to close the pole pieces together, grip more firmly the armature bearings and re-tighten the hexagonal nuts.
Low output from pick-up.	Examine the magnet for strength. The gaps may be too large. Test with the pick-up lying on a playing record, with headphones clipped across the leads from the pick-up. Look out for short circuit, either between the two leads or to earth, if necessary unsoldering leads at coil, and testing coil for continuity and signals with headphones and a battery. The D.C. resistance should be 6,000 ohms. NOTE.—Start testing from the pick-up, checking back if necessary, isolating each section of the circuit until a signal is received. Look out for short circuits or a short to earth. The output of the pick-up head itself may be immediately checked by unscrewing the small screw on the underside of the pick-up arm, withdrawing the pick-up, unsoldering the lead from the lugs, resting the pick-up on a playing record with headphones clipped on to the soldering lugs (see Fig. 13). If no signals are heard the pick-up head is faulty. If the pick-up head is found to be satisfactory, carefully test back the circuit and associated wiring and volume control for short circuit between the leads, discontinuity, and short circuits to earth. The volume control should also be examined for a satisfactory contact.
Output excessive.	Air gaps too small.
Output down.	(1) Gaps too large. (2) Weak magnet. (3) Damaged armature.
Output high pitched.	Bottom bearing too stiff.
Output low pitched.	Bottom bearing too loose.

(3) A single armature or reed, to which is attached the needle, pivoted in rubber buffers moving backwards and forwards between the pole pieces. The interior end of this armature, which passes up through the centre of the coil, is held by a small rubber damping sheet, which is in turn held in position by a clamping plate (see Fig. 11).

(4) The coil.

Fig. 15.—ADJUSTING THE MOTOR FOR VOLTAGE OF SUPPLY.

The Re-assembly of the Pick-up (Avoid Dust)

(1) Erect one pole piece on its end so that the coil is resting in it vertically; this will facilitate the insertion of the armature.

(2) Insert the armature so that the flattened portion enters through the centre of the coil in such a manner that it will appear at the top and so that the screwed end of the armature appears at the outer side of the pole piece.

(3) Carefully insert the rubber-bearing strips on either side of the point where the armature pivots coincide with the curved recesses in the lower edge of the pole pieces, and in such a manner that the two edges of the rubber strip do not come together at the point where the other pole piece will grip the armature pivots.

(4) Carefully slide the second pole piece over the coil in such a manner that the end of the rubber bearing strips protrude outwards and away from the lower surface of the poles.

(*Note.*—The point of a pin will be found useful to draw the rubber strips into correct position.)

(5) Holding the two pole pieces between the thumb and forefinger of the left hand, thus clamping the coil, armature and pole together, adjust the armature so that it normally situates itself equidistant from either pole.

(6) Screw up hexagonal nuts, thus securing poles in position in the moulded case, taking care that:—

(*a*) The needle is centred in the recess in the metal cover;

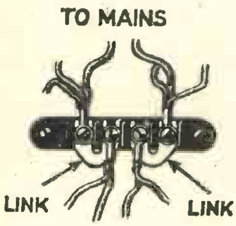


Fig. 16.—THE 521 A.C. MOTOR ADJUSTED FOR 100–130 VOLTS.

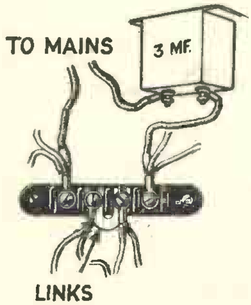


Fig. 17.—THE 521 A.C. MOTOR ADJUSTED FOR 130–160 VOLTS.

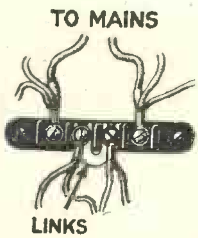


Fig. 18.—THE 521 A.C. MOTOR ADJUSTED FOR 200–260 VOLTS.

(*b*) That the armature is situated exactly between the two poles.

Note.—It will be found advisable not to screw the hexagonal bolts up too far until some slight pressure has been exerted between the moulded case and the ends of one of the pole pieces, to see that the rubber-covered bearings of the armature are firmly gripped.

(7) Replace the rubber damping sheet over the flattened end of armature so that the slit in sheet locates with blade of armature.

(8) Replace the clamping plate and screw down lightly.

(9) By lifting front edge of damping sheet, move clamping plate and damping sheet about until armature blade is exactly central between poles.

(10) Exert pressure, tending to close the pole pieces while finally screwing up the hexagonal bolts. Replace cover.

SEE THAT NO IRON FILINGS ARE PRESENT BETWEEN THE POLES OR ARMATURE.

THE 521 MOTOR

How the Motor Works

The principle on which this alternating current motor works is the same as that employed in most current meters.

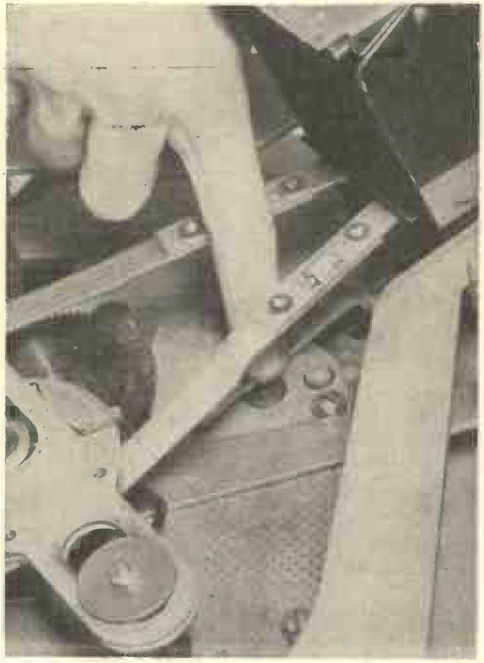


Fig. 19.—CONCEALED MOTOR SECURING SCREW IN "H.M.V." AUTOMATIC MECHANISM.

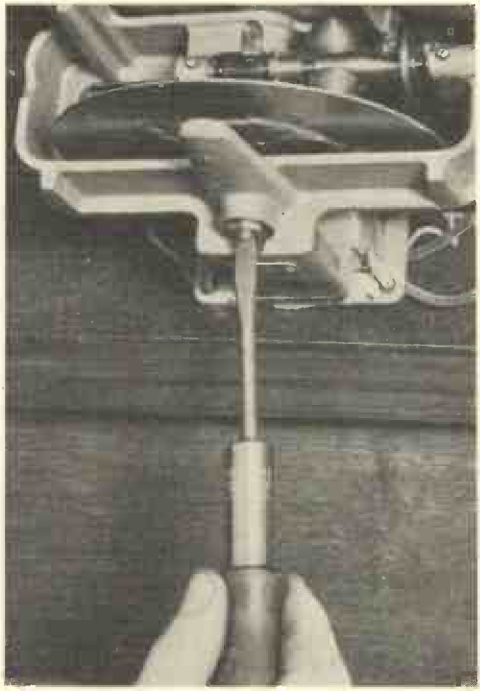


Fig. 20.—ADJUSTMENT OF LOWER MOTOR BEARING.

A metal disc is supported between two bearings, so that its edge locates between two electromagnetic fields produced by two electromagnets, one on top of the disc and the other at the bottom. The magnetic fields of these two magnets are so arranged that they induce into the disc certain currents which have the effect of turning the disc on its axis.

This motor is of exceedingly simple construction, and is likely to give very little trouble indeed. Its main parts consist of :—

(1) A metal frame which holds the lower and upper bearings of the disc and the two magnet units.

(2) Two electromagnet units.

(3) The disc and its spindle.

(4) The usual type of gramophone motor governor and regulator lever.

How the Electrical Supply Reaches the Motor

The supply to the motor is obtained from two pins on the side of the radio unit (the motor will not work if the

Fault Finding Table for His Master's Voice 521 Motor

Note.—Check supply to motor.

Symptom.	Possible Causes.	Suggested Action.
Motor will not revolve when main switch on and motor switch on.	Mechanical interference between parts of motor.	Test the turntable gently by hand. If free, look for trouble in the electrical circuit. If the turntable or spindle is very stiff, remove the turntable, and check automatic brake. If this O.K., remove motor and motor board from instrument. Check position of the driving disc in airgap between magnets; if necessary, adjust height by means of screw beneath lower bearing. Ensure that governor spindle bearings are correctly adjusted by slackening bearing set screws and adjusting pivots. Examine governor driving gear. Remove governor completely to test whether main spindle is free in bearings.
Motor revolves when turned by hand.	Suggests failure of electricity supply.	Test electrical circuit to motor by voltmeter or test lamp.
	If supply O.K. to motor. suspect motor circuit.	Remove motor and motor board from instrument. Check all magnet coil circuits for continuity and for *insulation from frame of the motor.*
	Feeble motor with increased hum.	Suspect burnt-out coil or disconnected condenser.
Motor starts satisfactorily, but slows down when needle lowered on record.	Voltage of supply incorrect for motor connections.	Check position of "series-parallel" links on motor terminal block. (See Figs. 16, 17, and 18).
	If connections correct, suspect faulty magnet coils. Check resistance.	Allow motor to run, feel coils. Potential coils should be at same temperature. *A coil hotter than others usually indicates that it is faulty. Resistance may be low.* Check resistances of all coils. (See page 255).
	Breakdown of one or more condensers.	Short-circuit terminals of each condenser in turn with piece of wire. If condenser can be short-circuited without affecting motor torque, condenser may be faulty. If torque still further reduced, condenser probably O.K.
	Mechanical stiffness.	Oil all bearings. Make sure automatic brake is completely disengaged from turntable rim when in playing position and that brake-lever collar O.K. Check adjustment of governor spindle and worm drive. Remove governor and spin turntable spindle between thumb and finger. If spindle feels stiff in bearings and oiling has no effect, try new spindle to determine whether original spindle or motor frame at fault. *See that regulator lever has not slipped off speed regulator screw on motor platform.*
Hum.	Loose coil winding.	Insert wooden wedge between outside of coil and iron laminations.
	Loose magnet unit.	Tighten screws securing unit to frame.
	Loose laminations.	Tighten screws securing laminations to unit frame. Adjust tension of these screws.
	Insecurely fastened motor.	Tighten motor securing bolts between motor and motor board. *If necessary,* insert felt washers between motor and motor board to adjust for correct turntable height.

Symptom.	Possible Causes.	Suggested Action.
Mechanical noise.	Driving disc fouling magnet laminations.	Adjust height of disc by screw beneath lower main spindle bearing. *Ensure* that coil unit is clamped up *squarely* to *motor frame*. Rattle may also be caused by incorrect voltage adjustment, or voltage adjustment too low for mains voltage.
	Governor springs.	If necessary, tighten all securing screws ; loose springs cause rattle. Ensure that each spring is screwed up in correct relative position. This may be found by slackening all spring-securing screws slightly then giving motor a few turns by hand. Then re-tighten screws.
	Excessive end play in governor spindle.	Governor spindle should have no perceptible end play. Adjust bearing pivots to quietest running position.
	Governor driving gear.	Worm wheel sometimes gives noisy drive ; should be replaced. *Centre line of worm wheel should be level with the axis of worm.*
Noisy motor.	Slack top main spindle bearing.	If upper main bearing becomes worn through running for long periods without lubricant, motor will be generally noisy, although units already mentioned are correctly adjusted. *In this case the motor should be returned to the Gramophone Co. Ltd.*, giving full details of trouble experienced.
Variation in speed.	Tighten main spindle. Tight governor bearings. Crazy governors. Disc rubbing pole laminations.	See " Crazy governors " below.
Crazy governors. (Roaring sound.)	Friction leather too hard. Lack of lubricant on leather.	Lubricate well and massage with pliers to encourage softness.
	Springs distorted. Tight governor bearings.	Adjust. Replace by complete set if necessary.
Sluggishness.	Tight governor. Congealed or unsuitable lubricant in bearings. Grease on disc.	Adjust bearings. Clean and re-lubricate.

radiogram is switched off) and through a switch operated by the tone arm.

The Most Likely Cause of Noise

The trouble most likely to occur with this motor is :—

(1) A slight jarring sound, due to the fact that the disc is periodically touching one of the magnet poles because it is slightly bent at some point of the circumference.

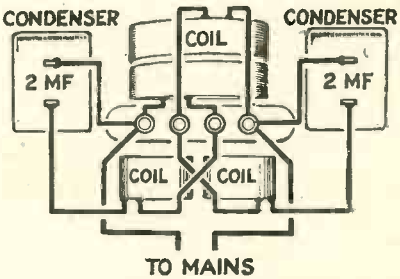


Fig. 21.—Arrangement of Coils and Condensers of 521 Motor.

(2) A whirring sound which indicates that the governor probably needs a little oil on the pad.

If the motor will not revolve, check the mains voltage at the motor itself when the set is switched on, by connecting a lamp or some other indicator across the terminals of the motor. This will avoid pulling the motor to bits to see what is wrong when the trouble may be merely that there is no current present for it to operate on.

Make absolutely certain that there is no obvious mechanical reason why the motor will not work before you decide to dismantle it.

Details of the Magnet Unit. (*See* Fig. 23).

This consists of :—

(*a*) A laminated steel core held in position by a brass clamping plate and screws " a," " b," " c " and " d."

Note.—Screws " e " and " f " and distance pieces on " g " and " h " serve only to keep the core clamped together, " g " and " h " securing the terminal strip in position.

(*b*) One reactive coil LR. Two non-reactive coils LN1 and LN2.

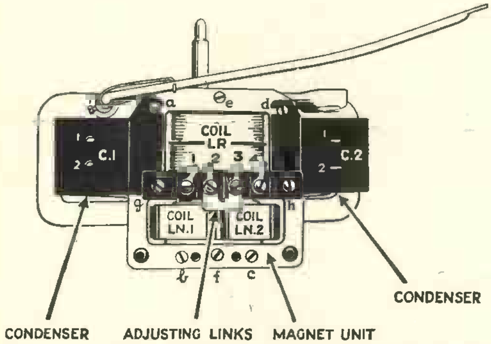


Fig. 23.—Details of the 521 Magnet Unit.

Note.—In all cases the inner end of the coil windings terminate in red wire, the outer windings terminating in yellow wires.

Electrical Resistance of Coils

Coil LR : D.C. resistance (top section), 35 ohms ; (bottom section), 35 ohms.

These values are measured as from lug 1 on C2 to voltage adjustment screw 3, and lug 1 on C1 to voltage adjustment screw 3, when adjusted as Fig. 23.

These values are measured as from lug 2 on C1 to screw 3 and lug 2 on C2 to screw 3 (Fig. 23).

Coils LN1 and LN2 : D.C. resistance 1,100 ohms each.

Condensers : C1 and C2—2 mfd. each.

How to Remove a Condenser

To remove condensers C1 or C2, unsolder leads to lugs, slack away screw " a " and distance piece on " g " or screw " d " and

Fig. 22.—Adjusting " H.M.V." Automatic Mechanism for non-eccentric Groove Record.

distance piece on " h " for C1 and C2 respectively (Fig. 23).

Warning.—Screws " g " and " h " must be slacked away from the back of the motor—in the case of " g," by passing a screwdriver below the governor to the back of the magnetic unit, and in the case of " h," by passing a screwdriver to the left of the main motor bearings from the back of the unit.

Note.—In the event of a condenser breaking down, any good make of condenser, Mansbridge type, capacity 2 mfd., may be installed by screwing on the motor-board or other convenient place temporarily, while replacement condensers are being secured.

How to Take the Magnet Unit Off

Withdraw screws " a," " d," " b " and " c," taking care not to lose conical spacer washers between the motor frame and the unit. The entire magnetic unit may now be withdrawn.

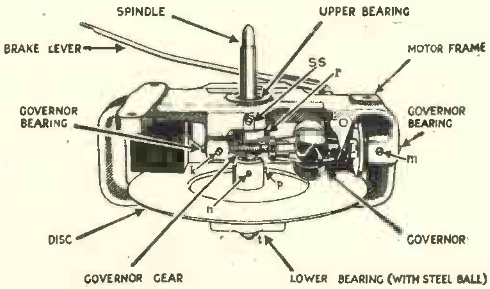


Fig. 24.—Details of the 521 Motor.

It is inadvisable to attempt to rewind coils on this unit.

How to Take the Governor Out (Fig. 24)

Slack off governor bearing screw "k" and governor bearing screw "m."

Slide governor gently towards the "k" bearing so that the bearing slips sufficiently far to allow the governor to be slipped out of the "m" bearing; then withdraw governor.

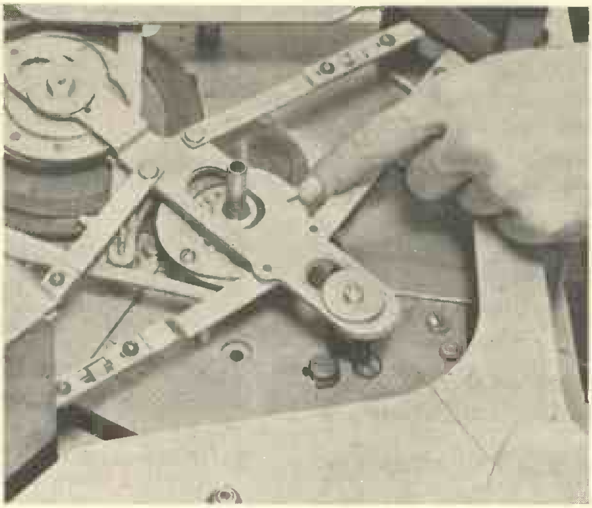


Fig. 25.—CLUTCH MECHANISM AND CLUTCH LEVER ON "HIS MASTER'S VOICE" AUTOMATIC MECHANISM.

For detailed information regarding the automatic mechanism, see the later section, which deals with servicing this apparatus.

Replacing the "K" Bearing (Fig. 24)

This bearing is fitted with a slot which engages with the bearing screw into which this screw must locate.

This operation should not be undertaken by inexperienced persons, and it is essential that the governor should not be handled roughly or, *more especially, dropped*.

How to Take Out the Disc

(1) Slack away screws "n" and "p" (Fig. 24).

(2) Slack away locking screw "r" in worm wheel hub.

(3) Withdraw spindle, worm wheel and rotor disc.

Important.—Locking screw "r" in governor driving gear and one grub screw in rotor disc should engage in the locating dimples in the main spindle when reassembling.

Do not lose steel ball in lower main bearing ("t").

The "Locating Plate" (Fig. 24, "ss")

This screw, which secures small metal plate on under-side of top bearing, is to prevent inexperienced persons from lifting the whole motor spindle and disc assembly when replacing or removing turntable and bringing disc in contact with magnet units.

The position of this screw and plate ("ss") is shown clearly in Fig. 24.

How to Lubricate the Motor

It is essential that correct lubricants should be used for this motor.

"HIS MASTER'S VOICE" greases and oils are chosen and carefully tested for freedom from harmful ingredients. It is especially important that the oil on the governor friction pad should be free from acids. For this reason always use "HIS MASTER'S VOICE" Oils and Greases.

What to do if the Governor Friction Pad is Worn

The clip holding this pad is bifurcated. The pad may be removed by opening the jaws of the clip with a screwdriver, thus loosening the grip on the pad, and enabling the new pad to be inserted; when the new pad has been inserted, close up jaws with suitable tool.

How to Put the Motor together again

(1) See that steel ball in lower bearing is present.

(2) See that one grub screw in inductor disc and in main spindle gear wheel are locating in special "dimples" on spindle.

(3) Adjust the lower bearing screw so that when motor is *right way up*, the disc is in correct position in magnet jaws—*i.e.*, does not touch either upper or lower poles when fully rotated.

(4) When the lower bearing has been adjusted, adjust the locating plate ("ss") so that it is impossible to pull the spindle and inductor disc assembly up so that inductor disc strikes upper magnet pole. Adjust plate ("ss") to stop this, but see that the plate is not rubbing the top of the main spindle gear wheel.

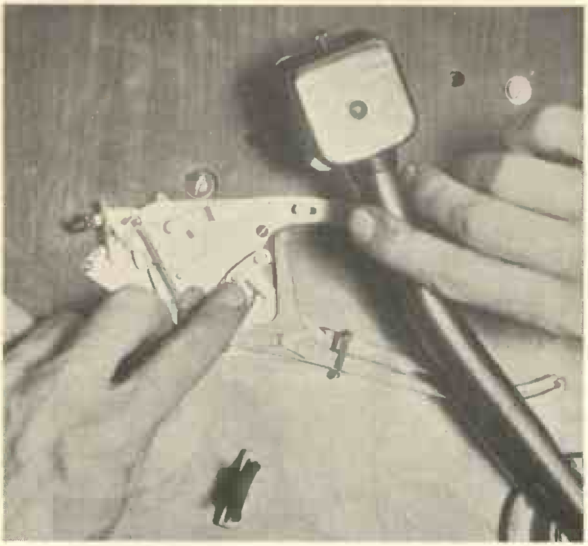


Fig. 26.—The Trip Action of the Automatic Brake.

See that the brake lever is not bent and that the pin on the underside of the pick-up arm is engaged correctly with the brake lever.

The locating plate may not require adjusting.

THE 521 PERMANENT MAGNET MOVING COIL LOUD SPEAKER

How it Works

The principle of operation of this loud speaker is that if a coil of wire carrying an electric current is placed in the field of a magnet and the current varies in the coil, the coil would tend to move with regard to the magnet, and if therefore the coil is attached to a cone, the cone will move, causing air waves which will give an air-wave reproduction of the electrical current variations in the coil.

In order that the greatest possible efficiency may be obtained, the air gap between the poles of the magnet is very small, and it is necessary that the coil should be correctly centred in this gap so that it can move in and out without touching the sides of the poles.

The most likely trouble to be encountered is a rattle or buzz, or the loud

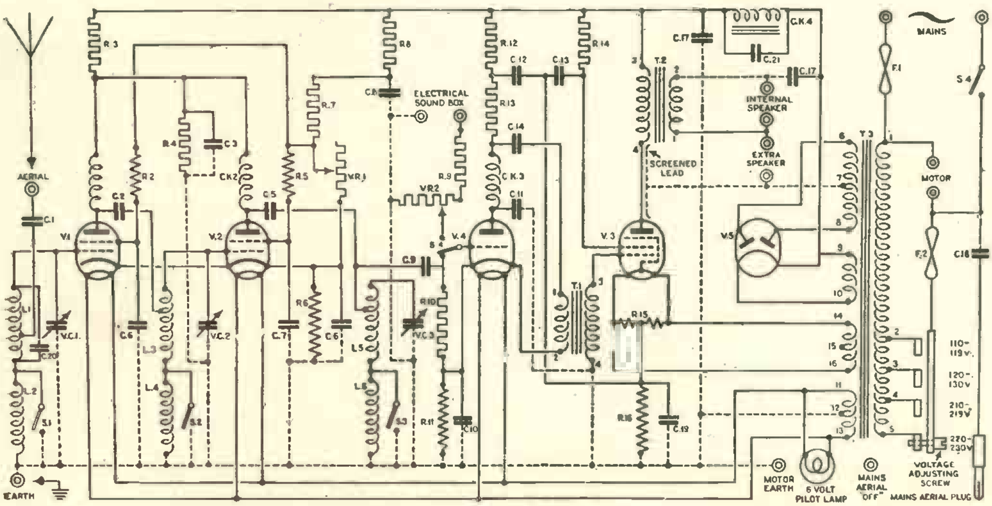


Fig. 27.—Circuit Diagram of the H.M.V. 521 Radiogramophone.

speaker seeming to choke on loud passages of speech or music.

If this is so be sure, before tackling the loud speaker, that it is the loud speaker which is at fault, by substituting one which is known to be "O.K."—it should be a low resistance one.

If the trouble is experienced with the test loud speaker connected, the place to look for something wrong is in the instrument, and not necessarily the loud speaker.

Distortion of this kind can be caused by a worn out, or defective, output valve—the P.T.625, or if it is experienced *only* on "Gramophone," the pick-up should be suspected.

"Buzz" is usually caused by the presence of dust between the coil and the poles of the magnet, or the fact that the cone has become moved and is touching one of the poles of the magnet.

How to get the Loud Speaker out

Switch off the instrument and detach the two wires from the clips on the loud speaker, and slacken off the two metal clips on either side of the loud speaker.

Do not switch on the set again until the loud speaker is reconnected to the instrument by a length of extension flex.

If the set is switched on without any loud speaker connected a severe electrical strain is put on the P.T.625 valve, which may damage it.

How to make sure that the Cone and Coil is Correctly "Centred" in the Gap

(1) Connect up speaker to the instrument and tune in a loud signal.

(2) Slightly slacken the centring screw and move cone very gently from side to side with an elliptical motion until the rattle ceases, gripping the cone with thumbs in front and fore-fingers behind.

(3) Then tighten the centre screw and test again on full volume.

If no transmission is available, slack the centring screw and the cone successively in four or five positions round the diameter and move it in and out at the same time. The side on which rubbing is occurring will be felt; move the cone in the indicated direction and tighten the centring screw again.

Fig. 28.—Adjusting Width of Record Jaws on H.M.V. Automatic Mechanism.

How to Remove Dust from Between the Coil and the Magnets

Take off the cone by:—

(1) Removing the felt ring; this is secured by adhesive to the metal cone-securing ring. This ring may consist of three segments.

(2) Withdrawing the cone centring screw and washer. A fibre washer is fitted on each side of the cone to prevent cutting of the material. Take care not to lose these or the metal spacing washer fitted behind the cone.

(3) Removing the eight screws and nuts which hold the cone-securing ring in position, being careful not to damage the cone or velvet while you are doing this.

(4) Removing metal cone-securing ring.

(5) Unsoldering the wires from the spring clips.

(6) Lifting one side of the cone, ascertaining that the leads from coil are quite free, and removing cone. Do *not* lose the

washers which are thus released from behind the cone.

Cleaning the Gap

If a light from a pocket torch is shone on the back of the magnet between the arms of the magnet, so that it shines up through the gap, any particles of dust can generally be clearly seen, and can be removed by a small strip of plasticine.

Blowing down the gap, or the use of a brush will often effect a temporary cure, but may cause a return of the trouble, since the dust is merely blown on to another part of the magnet, and will frequently return in time to the gap and cause a recurrence of the trouble.

How to Replace the Cone and Coil

Arrange the unit in a horizontal position, then place the metal spacing washer and fibre washer over the hole for the cone centring screw. Now insert the centring screw, with its washers, through the cone, then drop the cone into position and lightly tighten the centring screw. Take care to see that the holes in the rim of the cone register with the hole in the frame. Now screw up metal ring and connect the coil leads, refastening the felt ring with seccotine or similar adhesive.

The coil may now be centred as described before.

A " Dis " Coil

If no sound at all comes from the loud speaker, and a test with another loud speaker shows that the set is functioning correctly, it may be that the wire of the coil, which is very fine, has broken, and the coil is " dis " or no longer electrically continuous.

How to Test the Coil

Place a pocket-lamp battery—see that this is all right first—with one contact on one lead from the coil and the other connected to one tag of a pair of earphones, then touch the other lead from the coil with the other tag of the earphones—you should hear a distinct " click." If you don't, you may take it that the coil is " dis." While not attempting to re-wind the coil, which is the work of an expert, it is worth while making sure that the leads from the coil are O.K., and that they are not the cause of the trouble instead of the coil itself.

THE VALVES OF THE H.M.V. 521 RADIOGRAMOPHONE AND WHAT THEY DO

High Frequency Stage

The MS.4 Valves.—(3rd from left and 2nd from left). These are the two high frequency valves which contribute the reaching out qualities of the instrument.

It is these valves which should be suspected at once if the range and general radio performance of the 521 falls off.

These valves glow, and should be slightly warm. (If they are sprayed with metal paint, however, no glow will be visible.)

Detector Stage

The MHL.4.—This is the detector valve, which makes audible the hitherto inaudible radio signals which the two MS.4 high frequency valves have amplified.

This valve also is used as a sound amplifying valve when the switch is in the " gram " position for playing records. The signal from the electric pick-up being connected to the MHL.4 valve by the switch—amplified and passed to the PT.625 valve.

A new MHL.4 valve should be tried if either radio or gramophone performance fall off. The MHL.4 valve only glows very slightly, but should be warm at the top.

Output Stage

The PT.625.—This valve is the Pentode power valve or output valve, which finally amplifies both radio and gramophone reproduction, and passes the amplified signals to the loud speaker.

If this valve is worn out, it will cause not only weak reproduction of radio and gramophone, but also distorted quality of reproduction.

This valve does not glow, but it should be hot to the touch after the set has been switched on for a minute or two.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION VI—CONDUCTORS IN A MAGNETIC FIELD

THE following article is of the highest importance to every practical man who wishes to grasp thoroughly the action of coils, transformers, chokes, head-telephones, all types of loud speakers, as well as to have a clear idea on the action of various screening devices in a wireless receiver. In addition to this the material contained in the following pages is also essential to the complete understanding of the action of alternators, dynamos, motors and allied apparatus. For this reason the author invites his readers to study closely the phenomena described and to devote some time to thinking on the subject while going over, once more, the illustrations and the explanatory notes given in the first section.

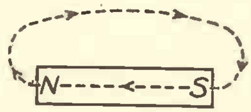


Fig. 1.—Showing how in an Ordinary Magnet the Lines of Force start at the North Pole and Terminate at the South Pole.

The Magnetic Field

We are now, more or less, familiar with the various aspects of the magnetic field and understand clearly that such a field consists of a number of lines of force spreading in three dimensions all round a magnet.

Lines of Force of an Ordinary Magnet

We also know that magnetic fields react upon each other, producing either attraction or repulsion in accordance with the direction of the lines of force. In the case of an ordinary magnet lines of force start at the north pole and terminate at the south pole as illustrated in Fig. 1.

Two Magnets with Unlike Poles

In the case of two magnets with two unlike poles facing as in Fig. 2, the lines of force flowing in the same direction combine into a single system as shown in Fig. 3, and attraction takes place between the unlike poles. In the case of like poles shown in Fig. 4 the lines of force are flowing in opposite directions, and in order to find "elbow room" are pushing each other aside with repulsion of like poles as a result.

What happens when an Electron is placed in a Magnetic Field

Now consider an electron, rapidly whirling in its orbit around its atomic

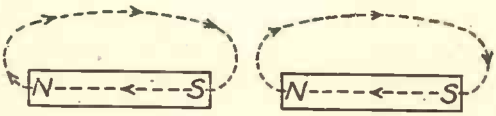


Fig. 2.—Two Magnets with Two Unlike Poles Facing.

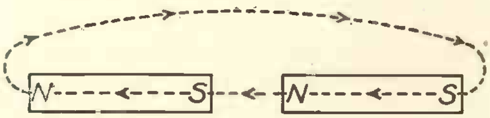


Fig. 3.—Showing how Lines of Force of Two Magnets shown in Fig. 2 combine into a Single System.

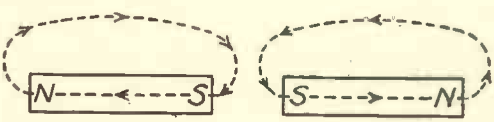


Fig. 4.—Flow of Lines of Force in the Case of Like Poles.

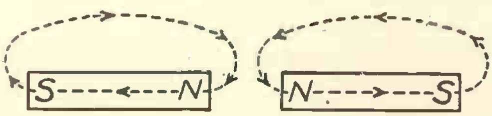


Fig. 5.—Another Example of Flow of Lines of Force in the Case of Like Poles.

nucleus, as a minute electric current accompanied by its own magnetic field (the magnetic effect of electrical current). When such an electron happens to be placed in a magnetic field due, say, to a permanent magnet it will suffer either attraction or repulsion in accordance with the direction of the lines of force of the surrounding magnetic field.

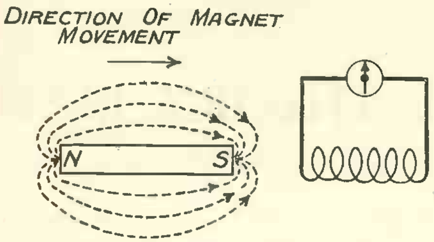


Fig. 6.—THIS SHOWS A MAGNET ADVANCING TOWARDS THE END OF A COIL OF WIRE FORMING PART OF A CLOSED CIRCUIT, WITH ITS SOUTH POLE LEADING.

This being the case, it is clear that when a conductor is placed in a magnetic field the electrons resident in the atoms of the conductor and for the time being rotating around the nucleus only and not jumping from atom to atom (there is no current flowing in the conductor) will be acted upon by the lines of force of the magnetic field. If the magnetic field is *at rest* it will slightly displace the electrons in their orbits but will not be able to exercise sufficient force upon these electrons so as to cause them to migrate from atom to atom and thus produce a flow through the conductor, a flow which we call an electric current. But, should the lines of force of the magnetic field be *moving*, they will exercise a drag upon the magnetic field surrounding the electrons and will cause them to move as well.

Effect of a Moving Magnetic Field on Electrons

This means that *a moving magnetic field is capable of causing a movement of electrons in a neutral conductor, i.e.*, a conductor to which no E.M.F. is applied externally.

For this to happen two conditions must be fulfilled. In the first place for the proper orientation of the reacting magnetic fields the lines of force of *the magnetic field acting upon a neutral conductor must be at right angles to it*. Secondly, if a current is to flow in the conductor under the influence of the moving lines of force *the conductor must form a closed circuit.*

The moving magnetic field when bringing the electrons in the atoms of the conductor into motion will produce an excess of electrons per atom at one point of the circuit and a deficit of electrons per atom at another point, by mere transference of electrons. In this manner the moving magnetic field will establish an electromotive force between the two points and will maintain this E.M.F. all the time it is in motion. The maintained E.M.F. will cause a current to flow in the closed circuit, a current which will persist all the time the E.M.F. exists, *i.e.*, all the time the magnetic field is in motion.

Effect of Permanent Magnet on Coil of Wire forming part of a Closed Circuit

Now, let us see what happens when a permanent magnet is brought near a coil of wire forming part of a closed circuit.

In Fig. 6 the magnet is shown advancing towards the end of the coil with its south pole leading. As soon as the lines of force of the magnetic field due to the permanent magnet cut the turns of the coil at right angles, electrons in the coil will be displaced, an E.M.F. established across the ends of the coil and a current will flow through the coil. This current, owing to the magnetic effect of the electrical current (the individual magnetic electron fields combining into a single field), will be accompanied by its own

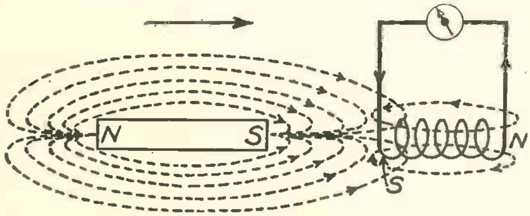


Fig. 7.—THIS SHOWS WHAT HAPPENS WHEN THE LINES OF FORCE OF THE MAGNETIC FIELD DUE TO THE PERMANENT MAGNET CUT THE TURNS OF THE COIL AT RIGHT ANGLES.

Electrons in the coil are displaced and an E.M.F. established across the ends of the coil, so that a current flows through the coil.

magnetic field, and we shall have a state of affairs as depicted in Fig. 7.

When the Coil behaves like a Magnet

Since there is a magnetic field around the coil now, the latter will behave like a magnet and will possess a magnetic pole at each end. On investigating the polarity of the coil end nearer to the magnet south pole, say with a small compass needle, we shall find that the coil forms an opposing, *i.e.*, a south pole at the near end, as if trying to resist the advance of the magnet's lines of force and repel them.

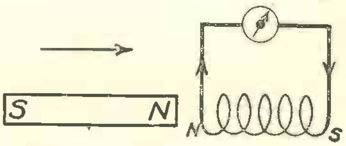


Fig. 8.—If a Magnet is leading with its North Pole the Current in the Coil *induced* by the advancing Magnetic Field will be such as to form at the near end of the Coil an opposing or North Pole.

(Lines of force omitted for clearness.)

Similarly, if the magnet is leading with its north pole, the current in the coil *induced* by the advancing magnetic field will be such as to form at the near end of the coil an opposing or north pole as shown in Fig. 8 (the lines of force are now omitted for clearness).

Effect of Advancing and Retreating Fields

In this latter case, it is very interesting to note that while the magnet is advancing with its north pole leading towards the near end of the coil, the coil forms an opposing north pole at the " menaced by the invasion " end, but when the same pole of the magnet is made to retreat, *i.e.*, move back again, the induced current in the coil will reverse, reversing the polarity of the near end as shown in Fig. 9. The reason for this is, naturally, that the advancing field has a different pull on the electrons as compared with the retreating field.

Important Points

To sum up :

(1) A moving magnetic field will induce a current in a closed coil, when its lines of force cut at right angles the turns of the coil.

(2) The current will persist all the time the magnetic field is moving and will cease as soon as the field ceases to move.

(3) The current flowing in the coil will flow in such a direction as to form an opposing magnetic pole at the end of the coil towards which the magnet pole is advancing.

(4) When the south pole of a magnet is advancing towards the coil the near end of the coil forms an opposing south pole, and when the south pole of the magnet is retreating the near end of the coil will form an attracting north pole, the current in the coil being reversed. If a north pole of a magnet is advancing the coil will form an opposing north pole reversing it to a south pole as soon as the north pole begins to retreat.

(5) This means that the induced current in the coil is always in such a direction as to oppose the action of the advancing or retreating pole.

Direction of Polarity

As far as the question of polarity of the ends of the coil is concerned, it should be noted that when the current is flowing through a loop of wire in the direction of the movement of the clock hand (clockwise direction) the loop acquires a north polarity (Fig. 10), and when the current is flowing in the opposite direction (anti-clockwise) this polarity becomes a south one (Fig. 11).

You will find that these two statements disagree with the usual text-books. But those still assume that current flows from the positive end of the cell to its negative end, while the reverse is the case.

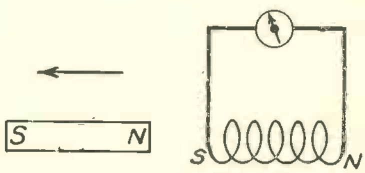


Fig. 9.—Effect of Advancing and Retreating Fields.

Showing how polarity is reversed when the magnet is moved back again.

Electromagnetic Induction

The action of the lines of force of a magnetic field upon the planetary electrons in the atoms of a neutral conductor in that a current is induced in the conductor is called *electromagnetic induction*. The more numerous the lines of force of the influencing magnetic field and the more rapid the movement of the lines of force in space the stronger the induced current.

Alternators and Dynamos

It is thanks to the facts described above that it has been possible to construct such machines as the alternator and the dynamo. In the case of these machines a number of closed conductors are made to rotate in a magnetic field produced by a number of electromagnets and have currents induced in them while the rotating conductors cut the lines of force of the magnetic field at right angles at a certain speed. It does not matter which of the two moves the conductors or the lines of force of the magnetic field, the action is the same.

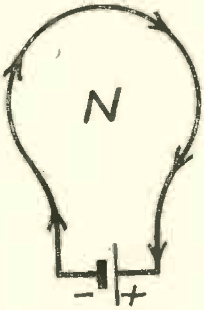


Fig. 10. — Direction of Polarity of the Ends of a Coil.

When the electrons are flowing through a loop of wire in the direction of the movement of the clock hand (clockwise direction) the loop acquires a north polarity.

Magnetic Field round a Conductor when a Current is Flowing

Now let us make a closer acquaintance with the magnetic field produced around a conductor when a current is flowing through the conductor.

We already know that when a current flows through a conductor there is a magnetic field consisting of concentric lines of force around the wire which represents the conductor. In Fig. 12 we see that when the current is flowing in a downward direction the lines of force are flowing in anti-clockwise direction, and when the current is reversed the direction of the lines of force of the magnetic field is also reversed (Fig. 13). These two diagrams, 12 and 13, are at variance with the text-books and contradict the famous corkscrew rule, p. 220, but in the corkscrew rule it was assumed that the current is flowing from the positive to negative. *Here we are considering flow of electrons.*

Since a moving magnetic field will induce a current in a closed conductor it does not matter how this magnetic field is produced. This can be done with the help of an ordinary magnet, or with the help of an electric current flowing in a conductor.

Making and Breaking a Circuit

Let us take a circuit such as shown in Fig. 14, which consists of a coil of wire, two cells and a key for closing and opening the circuit, or, as the engineers say, for making and breaking the circuit. When the key is closed (Fig. 15) a current will flow from the negative side of the cells, through the coil and back to the positive side of the cells. This current will produce a north magnetic pole at the left end of the coil and an opposite pole at the other end. The magnetic field will arrange itself around the coil as shown. Before the key is closed there is no current flowing through the coil and, therefore, there is no magnetic field around the coil.

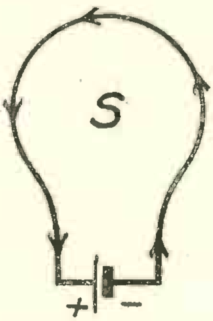


Fig. 11.— Direction of Polarity of the Ends of a Coil.

When the electrons are flowing in the opposite direction to that in Fig. 10, *i.e.*, (anti-clockwise) the polarity becomes a south one.

Strength of Magnetic Field depends on the Current

When the key is closed the current does not come up to its full strength at once, but takes a little time to do so (the reason for this we shall see later), and therefore, since the strength of the magnetic field depends on the current (as the current grows the magnetic field grows, as the current diminishes the magnetic field diminishes, and as the current stops the magnetic field disappears), while the current is coming up to its full strength the magnetic field will also gradually grow, increasing in the number of lines and spreading in space, so that its lines of force will be *moving*. See also pp. 10 and 11.

How a Moving Field is produced

The same will happen when the current is cut off and collapses gradually. The magnetic field will also collapse gradually, contracting on itself, and once more the lines of force will move. Thus, an increasing or a collapsing magnetic field is a *moving field*. When the key is closed and the current reaches its final steady value the magnetic field will also reach its steady value, and will remain stationary around the coil. It is clear, therefore, that in the case of a circuit supplied with cells the magnetic field around the circuit will be in motion only when the circuit is being made or broken.

For this reason, with an arrangement such as depicted in Fig. 16, there will be a moving magnetic field around the left-hand coil only at the moment when the switch is being closed or being opened. While the field around the left-hand coil is in motion its moving lines of force will cut the turns of the right-hand coil at right angles, inducing in it a current in the opposite direction. When the key is open and the circuit is broken the current collapses and with it the magnetic field (Fig. 17), the current in the right-hand coil under the influence of the retreating magnetic field (remember the retreating pole of a magnet) will reverse its direction.

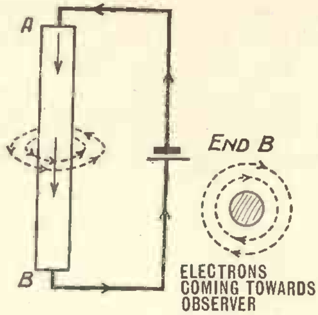


Fig. 12.—This shows that when Electrons are flowing in a downward direction the Lines of Force are flowing in an anti-Clockwise direction.

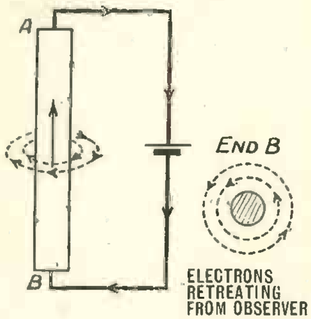


Fig. 13.—When the Electron flow shown in Fig. 12 is reversed the direction of the Lines of Force of the Magnetic Field is also reversed.

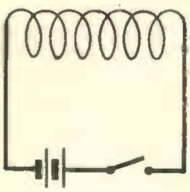


Fig. 14.—How the Magnetic Field arranges itself round a Coil (1)

This shows a circuit consisting of a coil of wire, two cells, and a key for closing and opening the circuit. The key is shown open, and no current is flowing through the coil.

Alternating Current

Up to this moment we have discussed steady, direct E.M.F.s and direct currents. There is another kind of an E.M.F. and current called respectively an *alternating E.M.F.* and *an alternating current*. An alternating E.M.F., and therefore an alternating current, varies in strength from instant to instant, starting from nothing and gradually growing to some maximum value. Once this maximum value is reached the strength starts to diminish and is gradually reduced to nothing again. After this the E.M.F. begins to grow *in precisely the same way as before*, only in the opposite direction, till it reaches a maximum and comes down to nothing again.

Such reversal in direction may happen once a second or it may happen any number of times up to and over a million times a second. The frequency with which such reversals in direction take place every second is called simply *the frequency* of the E.M.F. or current.

A Complete Cycle

In the case of an alternating current, since the strength of any current depends on the number of electrons taking place in the flow at any instant, the varying strength from zero to maximum and from maximum to zero again merely means that during each small fraction

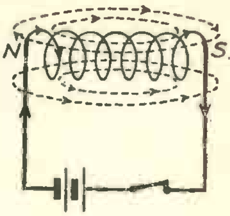


Fig. 15.—How the Magnetic Field arranges itself round a Coil (2).

Here the key is shown closed. A current flows from the negative side of the cells through the coil and back to the positive side of the cells. This current will produce a north magnetic pole at the left end of the coil and an opposite pole at the other end.

of a second different numbers of electrons are flowing through the circuit as a whole. The reversal of direction merely means that if in the first place electrons were flowing from left to right, on reversal they will flow from right to left. A complete cycle of events, *i.e.*, electrons gradually increasing in numbers from nothing to a maximum and then diminishing from maximum to nothing again (no current flowing at all during this instant) and then repeating precisely the same periodic growth and decay in the opposite direction, is called a *cycle*.

Behaviour of Alternating Current in a Circuit

Fig. 18 will give some idea of the behaviour of an alternating current in the circuit. To make the idea clear the varying strength of current and direction is shown on a film strip. Note that the instants 1, 7 and 13 during the complete cycle (from 1 to 13) are identical. Also that 2, 6, 8 and 12 are the same, only the last two are in the opposite direction. Similarly, instants 3, 5, 9 and 11 are the same. The maxima 4 and 10 are also identical. In studying this diagram it should be remembered that during any single instant the depicted condition applies to the whole of the circuit, different numbers of electrons flowing round the circuit at each instant—a small fraction of a second.

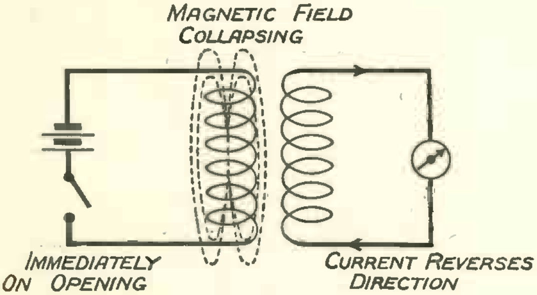


Fig. 17.—How a Moving Magnetic Field is Produced.

When the key is open and the circuit is broken, the current collapses and with it the magnetic field. The current in the right-hand coil under the influence of the retreating magnetic field (remember the retreating pole of a magnet) will reverse its direction as shown.

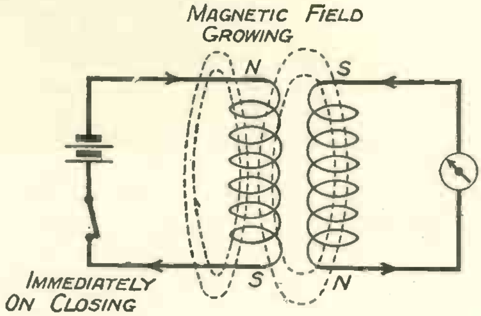


Fig. 16.—How a Moving Magnetic Field is Produced.

There will be a moving magnetic field around the left-hand coil only at the moment when the switch is being closed or opened. While the field around the left-hand coil is in motion its moving lines of force will cut the turns of the right-hand coil at right angles, inducing in it a current in the opposite direction.

Alternating Magnetic Field is always on the Move

Now, with such an alternating current, the magnetic field around the conductor through which the current is flowing must also be alternating. This means that following the variations in the intensity and direction of current, the magnetic field will start from nothing (no lines of force at all), will gradually increase its number of lines and their spread, spreading out to a maximum, then contracting gradually but quickly to nothing again, only to grow in the opposite direction and then collapse again. This means that *an alternating magnetic field is always on the move, never stationary, always pulsating in space around the conductor.* The greater the maximum value of current the greater the spread and the number of lines of the alternating magnetic field at the instant of maximum.

Alternating Current flowing through a Coil

In Fig. 19 is shown a coil connected to a source of an alternating supply. An alternating current is flowing through the coil and an alternating magnetic field is existing around the coil. Since the alternating magnetic field is always on the move and is

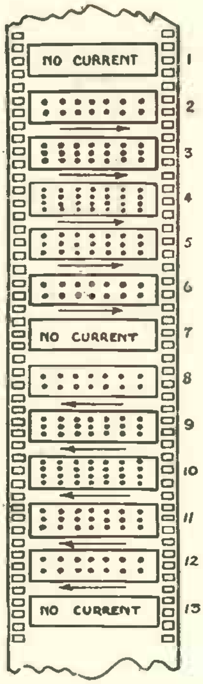


Fig. 18.—This gives some idea of the behaviour of an Alternating Current in a Circuit.

During any single instant the depicted condition applies to the whole of the circuit, different numbers of electrons flowing round the circuit at each instant in a small fraction of a second.

cutting the turns of the coil on the right at right angles, a current is induced in the right-hand closed circuit. This current following the variations of the alternating magnetic field must also be of an alternating nature. At any instant the distribution of the main currents in the two coils is as shown in Fig. 19.

But these currents are not the only currents flowing in the two coils. It has been stated that when a current starts in a conductor it does not come up at once to its full strength. The reason for this is that the local electrons in the atoms which are being invaded by the migrating electrons do not take this sort of thing kindly and do their best to resist the invasion. Their first line of defence is the ordinary repulsion which we know as *resistance*. The second line of defence will become apparent from Fig. 20. It is easily visualised that the magnetic field around a coil is not only existing in space around the coil as a whole, but that there are also local magnetic fields around each bit of wire in every turn of the coil. These local magnetic fields are due to the same alternating current and are also alternating. Since they are of an alternating nature, they are constantly moving, now growing, now collapsing on themselves. In doing so they cut their own conductors and the turns of wire adjacent to their own turns and thus induce currents in them, currents which we shall call local currents.

Local Currents

These local currents are in opposition to the main current flowing through the coil, being at every instant in a different direction to the main current (Fig. 20). The net result is that when the main current is growing the local currents, consisting of crowds of local electrons, are moving in the opposite direction and thus stop some of the electrons in the main flow from migrating. This sort of thing reduces the strength of the main current. When the main current is diminishing, the local electrons try to prevent its sudden collapse and are now flowing in the same direction with it, thus strengthening it for the time being.

Self-induction

This action of the local field is called *self-induction*, as the coil is inducing an additional current in itself. The degree of self-induction possessed by individual coils and depending on their shape, size, etc., is called the *self-inductance* of a coil.

Primary and Secondary

Returning now again to Fig. 19 we can realise that since there are currents flowing in both coils, the applied current in the left-hand coil and the induced

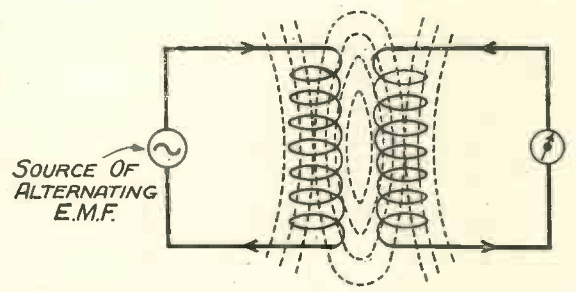


Fig. 19.—This shows a Coil connected to a source of an Alternating Supply.

An alternating current is flowing through the coil and an alternating magnetic field is existing around the coil. Since the alternating magnetic field is always on the move and is cutting the turns of the coil on the right at right angles, a current is induced in the right-hand closed circuit.

current in the right-hand coil, there are also self-induced currents flowing in each coil. But this does not end the story. This last point is very important, as no doubt you have recognised in Fig. 19 a pair of coupled coils such as the primary and the secondary aerial coils, or the secondary and the reaction coils. Let us call the left-hand coil *the primary*, since it has the applied E.M.F., and the right-hand coil *the secondary*.

The primary current flowing under the influence of the applied E.M.F. produces a magnetic field, which being in motion cuts the turns of the secondary coil and induces a current in it. Both coils are subject to the effects of self-induction which regulates the gradualness of any changes taking place in the flow of the two currents. But the secondary coil having a current flowing in it, produces a magnetic field of its own, a magnetic field which in moving will cut the turns of the primary coil and induce a current in it.

Three Currents in a Primary Coil

Thus, the primary coil will have at any instant three component currents flowing in it: 1, the current flowing under the influence of the applied alternating E.M.F.; 2, a current flowing on account of self-induction; and 3, a current flowing by induction from the secondary coil. The state of affairs is now as shown in Fig. 21. You will note that I_1 is the main primary current, I_2 is the primary self-induction

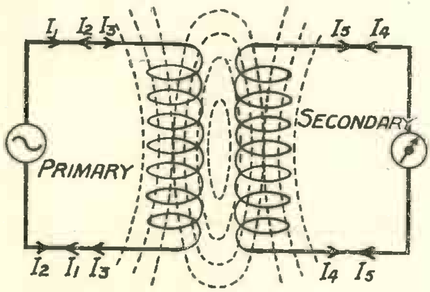


Fig. 21.—THIS SHOWS HOW A PRIMARY COIL WILL HAVE AT ANY INSTANT THREE COMPONENT CURRENTS FLOWING IN IT.

These are 1, the current flowing under the influence of an applied alternating E.M.F.; 2, a current flowing on account of self-induction; 3, a current flowing by the induction from the secondary coil.

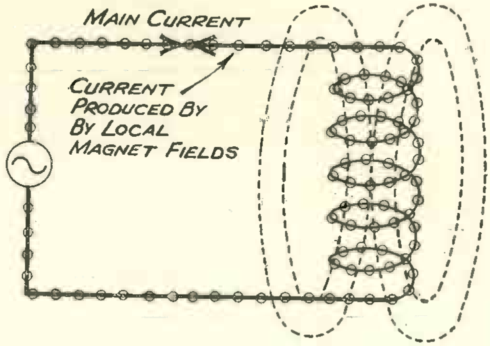


Fig. 20.—SHOWING HOW LOCAL MAGNETIC FIELDS AROUND EACH BIT OF WIRE IN EVERY TURN OF THE COIL ARE IN OPPOSITION TO THE MAIN CURRENT FLOWING THROUGH THE COIL, BEING AT EVERY INSTANT IN A DIFFERENT DIRECTION TO THE MAIN CURRENT.

current, I_3 is the primary current induced by the secondary coil, I_4 is the secondary current induced by the primary coil, and I_5 is the secondary self-induction current. The directions of currents in Fig. 21 are depicted instantaneously.

You will notice that I_1 and I_3 always flow in the same direction. This is because I_4 is the reverse of the primary current I_1 and I_3 is the reverse of I_4.

Mutual Induction

This induction of the secondary current by the primary and of additional primary current by the secondary is called *mutual induction* and the degree of mutual induction possessed by two coils is called the *mutual inductance* of the coils.

The closer the two coils are brought together the greater the mutual inductance. Thus, mutual inductance between two coils can be controlled by varying the distance between them. Two coils near each other with interacting magnetic fields are called *coupled coils*. The distance between the coils is referred to as the *degree of coupling*. If the coils are close together the coupling is said to be *tight*, if they are a distance apart the coupling is said to be *loose*.

Inductance is measured in units, called *henries*. As one henry is too large a unit for wireless work, a thousandth of a henry is used and is called a *millihenry*.

We call one closed loop of lines of

magnetic field passing through a turn of wire one *linkage*. Three lines of force linked with one turn will give three linkages, so will one line of force linked with three turns of wire.

One henry is the inductance of a coil that will set up 100,000,000 *linkages per ampere of current passing through it.*

Having made ourselves familiar with the manner of working of coils, we shall study in the next section the condensers so that we are able to consider the two together.

QUESTIONS AND ANSWERS

What is the Underlying Principle of the Dynamo?

The operation of the dynamo depends on the fact that if a coil of wire is moved through a magnetic field so as to cut across the lines of force, an electromotive force, or voltage, will be generated in the coil.

What is the Principle of an Electric Motor?

The fact that if a coil of wire carrying an electric current is brought near the pole of a magnet, the wire will tend to move across the lines of magnetic force.

In what Way does the Modern Theory of Electricity clash with the Corkscrew Rule?

In the corkscrew rule as described on p. 220, the current is assumed to flow from positive to negative. The electronic theory states that an electric current is due to the flow of electrons *from negative to positive*.

If the direction of electron flow is considered, the old corkscrew rule must be reversed.

What is the Difference between Direct Current and Alternating Current?

Direct current flows steadily in one direction. Alternating current flows first in one direction and then in the opposite direction. In the house mains these reversals usually take place at the rate of fifty a second. In a wireless aerial the reversals take place at the rate of about a million times a second.

What is one of the Most Important Properties of Alternating Current?

The fact that it can be easily transformed to a higher or lower voltage by means of a transformer, as explained on pp. 10 and 11.

Why cannot a Direct Current Supply be Transformed in a Similar Manner?

Because a transference of energy between primary and secondary coils of a transformer can only take place whilst the magnetic flux is altering.

A direct current supply to the primary produces a steady magnetic effect, so that after the first rush of closing the circuit, no further transference of energy from primary to secondary can take place.

What are the Essentials of a Transformer?

Primary coil; secondary coil; and a magnetic core.

What is Self-induction?

This is the action of the local field, as the coil is inducing an additional current in itself.

What is Mutual Induction?

This is the induction of the secondary current by the primary and of additional current by the secondary.

What is meant by Coupled Coils?

This means that two coils are near each other with interacting magnetic fields.

How is Inductance measured?

Inductance is measured in units called henries. As one henry is too large a unit for wireless work, a thousandth of a henry is used and is called a millihenry.

Is there any Difference between the Magnetism produced by a Current flowing round a Coil and that of a Permanent Magnet ?

There is no essential difference.

Then why are Electromagnets always used in large Dynamos and Motors, in preference to Permanent Magnets ?

Because the magnetic force or flux can be made much stronger by using electromagnets.

Is there any Limit to the Strength of an Electromagnet ?

Yes. After a certain point, the iron core becomes " saturated " with the magnetic flux and increase of the magnetising current produces little or no increase in the magnetic flux.

What Bearing has this on the Design of Wireless Components ?

Low frequency transformers must on this account be designed so that the iron core is large enough to prevent any possibility of the core becoming " saturated " or approaching the saturation point of the iron. If this is not done serious distortion is liable to occur, owing to the fact that the variations of output current will not correspond to the variations in the input current.

What are the Three Component Currents that flow in a Primary Coil at any Instant ?

1. The current flowing under the influence of the applied alternating E.M.F.

2. The current flowing on account of self-induction.

3. The current flowing by induction from the secondary coil.

Why is it that when a Current starts in a Conductor it does not come up at once to its full Strength ?

This is because the local electrons in the atoms which are being invaded by the migrating electrons do their best to resist the invasion. Their first line of defence is the ordinary repulsion which we know as resistance. The second line of defence consists of local magnetic fields which set up local currents. These local currents are in opposition to the main current flowing through the coil, being at every instant in a different direction to the main current.

What is one of the most important Points regarding the " Self-induction Current " in the Primary of a Transformer ?

The fact that it *opposes* the applied E.M.F. This is the reason why a mains transformer when connected to, say, a 220-volt mains supply, only draws a very small current from the mains. The resistance of the primary coil may be only 500 to 1,000 ohms but the current flowing through the primary when the transformer is not under load is always very much less than would follow from Ohm's law, owing to the fact that the " self-induction " current opposes the applied voltage.

THE PRINCIPLE OF THE MOVING COIL LOUD SPEAKER

SHOWN IN PICTURES

THERE are to-day many ingenious designs of moving coil loud speakers, some having magnets energised from the mains after the current has been rectified and smoothed, others employing powerful permanent magnets. The constructional details of the various types will be dealt with later, but the pictures herewith will serve to show the underlying principle. This may be briefly stated as follows :—

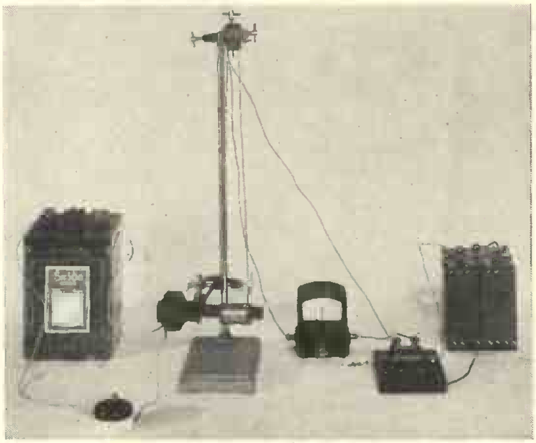


Fig. 1.—This shows the apparatus to be used in these simple experiments. In the centre is a bundle of soft iron wire mounted on a stand and having at one end a coil of wire connected in series with a switch and low tension battery. At the other end of the iron core can be seen a light cardboard tube with a winding of fine wire on the outside. The ends of this winding are used for suspending this coil, and the winding is connected through an ammeter and tapping key to a dry battery of 4 cells.

A light coil suspended in a strong magnetic field tends to move to and fro in the field if the coil is supplied with a current of varying strength.

In Fig. 1 is seen the simple apparatus required for demonstrating the important principle. The apparatus consists of a low tension battery and switch connected in series with a coil of about 200 turns. The latter is slipped over one end of a soft iron core forming a simple electromagnet.

At the other end of the core is suspended a moving coil which can be supplied with current from a separate battery through a reversing key. When current is switched on in the moving coil, the latter immediately swings outwards as shown in Fig. 3. When the current is reversed the coil swings back towards the other end of the electromagnet.

In actual practice the moving coil is arranged between the magnet poles and, of course, the amount of movement is limited owing to the fact that one end of the coil is anchored to the diaphragm of the speaker. The fluctuations in the speech currents caused the coil to vibrate in sympathy with the current variations. These vibrations are communicated to the diaphragm, which thus reproduces the speech.

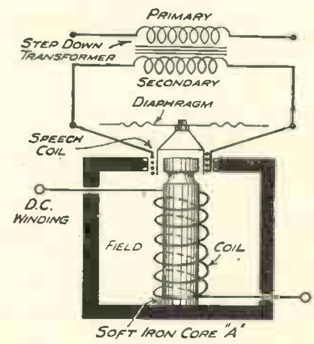


Fig. 2.—SECTION OF A MOVING COIL UNIT.

The reason why the moving coil speaker is so much more powerful than the older type is because by making the electro-magnet or permanent magnet sufficiently powerful, comparatively large movements of the diaphragm can be obtained with comparatively small speech currents.

In the older type of speaker, permanent magnets were used and the speech currents were sent round coils mounted on the magnets. The effect of these currents was to increase, or decrease, the strength of the original magnet which acted on a reed or diaphragm and caused it to vibrate in sympathy with the speech currents.

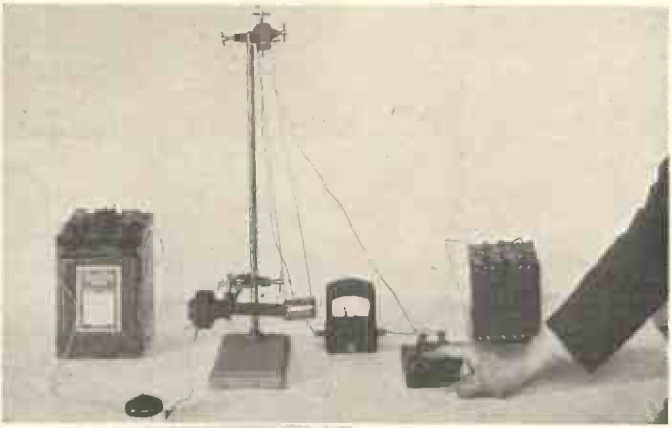


Fig. 3 (*Above*).—Note that the switch on the left has been closed and current is now flowing from the accumulator through the large coil turning the soft iron core into an electro-magnet. The switch in the moving coil circuit has been closed. Note the position of the coil.

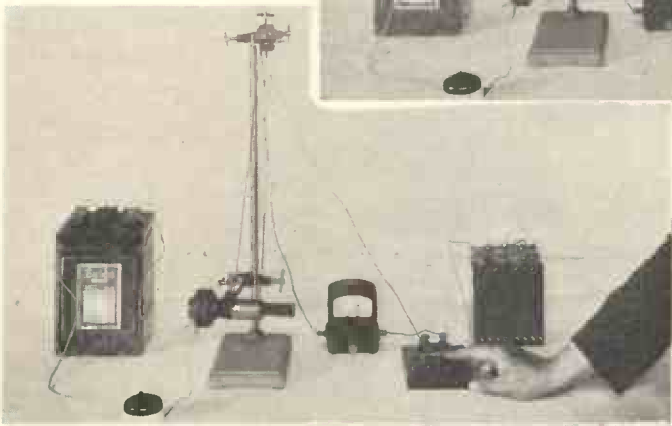


Fig. 4 (*Above*.)—Here we see the same conditions as in the previous pictures except that the direction of current flowing through the moving coil has been reversed. Note the new position which the coil has taken up.

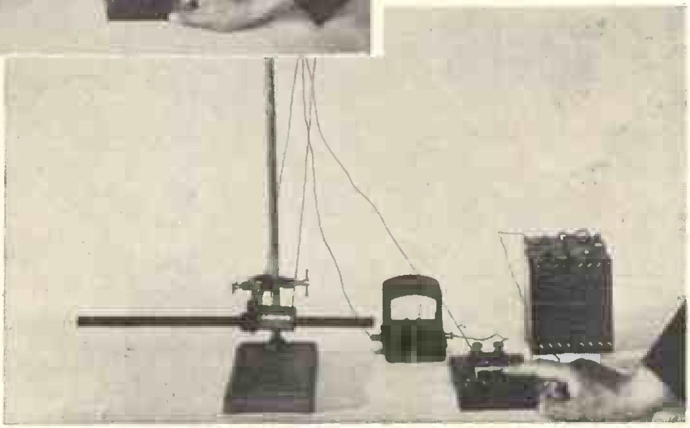


Fig. 5.—Here we see a permanent bar magnet being used in place of the electro-magnet. By reversing the current through the moving coil the latter can be made to swing to and fro along the magnet. This is the principle upon which the permanent magnet moving coil speaker operates.

It is easy to see that if a very strong permanent magnet was used in the older types of speakers the small speech currents would produce less effect on the total magnetism present, whereas with the moving coil system the stronger the original magnet the greater the power obtained from the currents circulating in the moving coil.

Other advantages of a mechanical nature are also obtained, owing to the fact that it is not necessary to use an iron diaphragm. These will be fully dealt with, together with the question of the baffle board in a later section dealing with the practical application of the principle which is here explained.

ALUMINIUM

PROPERTIES, USE AND WORKING

By EDWARD W. HOBBS, A.I.N.A.

ALUMINIUM is obtainable in the form of rolled sheets of various thicknesses from that of foil upwards, also drawn rods, tubes and strips of various sections. Castings are made in aluminium, but in general wireless work the rolled or drawn metal is mostly used.

The applications of the metal are too well known to require particularising, except perhaps to emphasise its growing popularity as a material of construction for chassis sets and for the shielding of components.

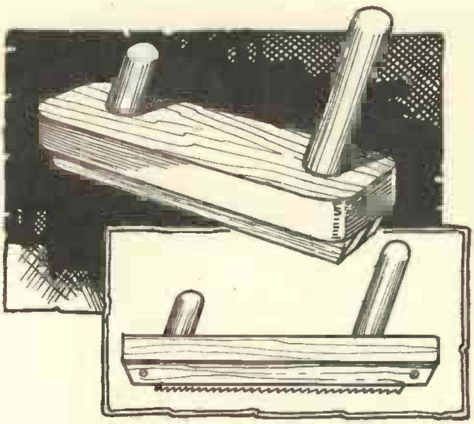


Fig. 1.—HOME-MADE HACKSAW.

With this simple device sheet aluminium can be sawn square and true.

Cutting by Hand

Thin sheets can be cut with scissors or with tinman's snips; another practical plan is to use a sharp strong jack-knife, guided by a steel or other straight edge, and cut on a suitable bed, such as a strong smooth board faced with stout cardboard. Lay a sheet of glass on the cardboard, then place the sheet metal on the glass.

This method is handy when cutting a special escutcheon for a tuning dial or any parts with a curved or fancy outline. If the knife is kept very sharp and the metal is not too thick, a perfectly clean cut can be accomplished and the edge of the metal will not require further trimming up.

An advantage of knife cutting is that the sheet is not buckled or distorted in any way, as is often the case when snips or scissors are used.

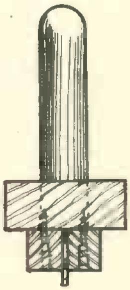


Fig. 2.—SECTION OF HACKSAW.

The two slips are screwed to the body and the saw blade clamped between the slips.

Sawing Aluminium

Thicker sheets can be sawn with a small "metal slitting" saw used in a lathe, or on one of the modern "universal" types of polishing head with sawing and drilling attachments.

The great point to watch when using a circular saw is to use such speed and feed rates as will ensure the chips clearing thoroughly, otherwise the teeth will clog and the saw become useless. A cutting speed of about 375 feet per minute is about correct, or, say, a spindle speed of 400 r.p.m. when using a 4-inch diameter cutter.

Run the cutter towards the work, the teeth cutting downwards towards the table. Feed as rapidly as the work will stand and use plenty of lubricant, such as soapy water or paraffin oil.

Curved shapes can be sawn with a hand or power-driven fretsaw if a "metal cutting" blade is used and constantly lubricated.

Special Hacksaw

Rods, bars, tubes and thick stuff generally can be cut in the usual way with a hacksaw having a medium tooth spacing. When cutting, exert only sufficient pressure on the forward stroke to ensure a clean cut, but on the return stroke

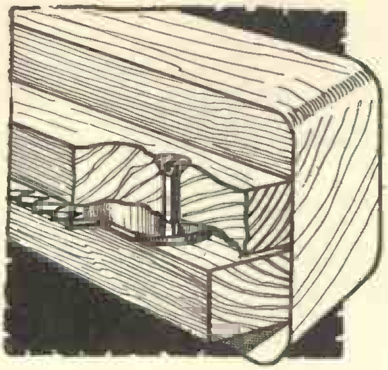


Fig. 3.—METHOD OF FIXING SAW-BLADE.

The saw-blade is ground away at the ends—to give clearance to the teeth—and is clamped between the two slips.

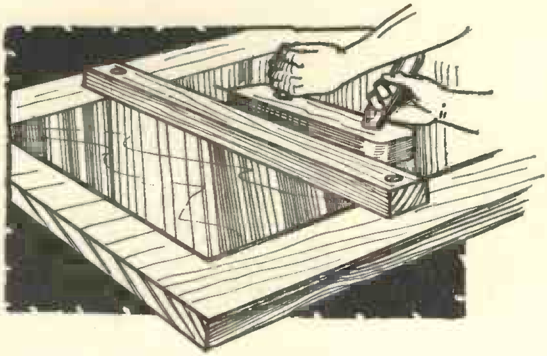


Fig. 4.—USING THE HOME-MADE METAL SAW.

The metal is clamped to the workbench, the saw worked liked a plane and guided against the straight-edge.

take care to keep the saw teeth clear of the cut, as by so doing the fatal tendency to clog is minimised. French chalk or paraffin oil are the best lubricants while hack-sawing.

A very useful home-made hacksaw is shown in Fig. 1, which will amply repay the small amount of time and trivial cost involved in making it. The saw is intended for cutting large sheets—such as those for a chassis—and to produce a clean straight and square edge, which will need little or no subsequent cleaning up.

Making the Saw Frame

The body of the saw frame is a piece of smooth, hard wood, 12 inches long, 2 inches wide and 1 inch thick,

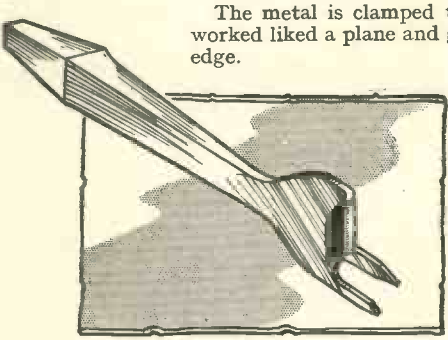


Fig. 5.—SPECIAL CENTRE BIT.

Circular holes can be drilled in thin sheet aluminium with a carpenter's centre bit filed to shape as here shown.

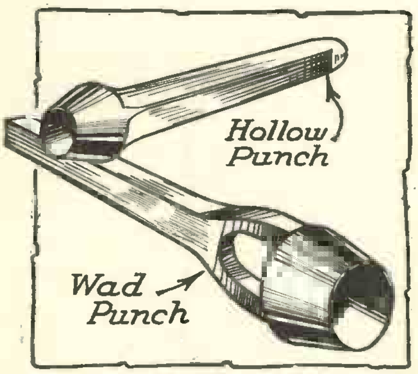


Fig. 6.—WAD OR HOLLOW PUNCH.

Discs can be punched out of sheet metal by means of a tinman's hollow punch or with a wad punch.

Fig. 7.—STRAIGHT FLUTED DRILL.

A drill of this kind gives best results when drilling holes in aluminium.

or thereabouts, to the underside of which are screwed two slips of oak, about $\frac{3}{4}$ inch deep and $\frac{1}{2}$ inch wide, extending the full length of the body. The sectional view (Fig. 2) shows these slips in place, screwed firmly to the body.

The slips must be parallel to the edges of the body and must have a gap between them about 3/1,000ths inch wide.

The next requirement is a piece of broom handle, about 8 inches long, which must be glued and screwed firmly into a hole drilled about $1\frac{1}{2}$ inches from one end of the body; a similar but shorter handle, about 3 inches long, is fixed in the corresponding position at the front.

Next, take an ordinary 10-inch hacksaw blade and grind away the teeth from the bottom part of the blade at each end as shown in Fig. 3, then place it in the slit between the wooden slips and fasten it with wood screws driven through the holes in the saw blade.

The use of this special saw is illustrated in Fig. 4. The method is to hold down the aluminium sheet by a cross-batten screwed or clamped to the bench, and work the saw in a similar manner to a plane and guide it by pressing it against the batten. In this way a perfectly straight true cut can quickly be made.

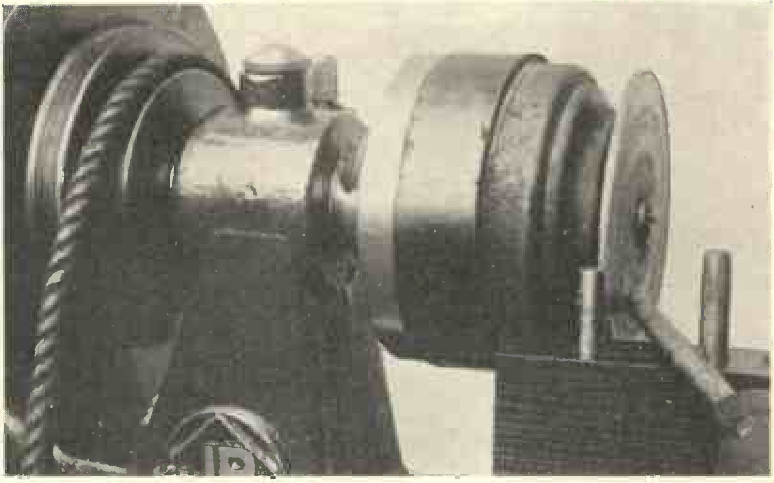


Fig. 8.—Spinning Aluminium in the Lathe.

A disc of metal is fixed to a wooden former chucked in the lathe. While the metal is revolving at high speed it is forced into shape by the spinning tool which is pressed against a peg on the slide rest or a block fixed to the lathe bed.

Parallel strips of metal can be cut if two saw blades are prepared and fastened together with a spacer strip of wood between them, the whole being screwed to the underside of the body.

Cutting Circular Holes

Holes from about ⅜ inch to 1½ inches diameter can be made through ordinary thicknesses of aluminium sheet with the aid of a specially-shaped carpenter's centre bit.

The centre bit is shown in Fig. 5. The prong or outer cutter is left intact, but the blade is filed away and rounded off somewhat, so that it will not cut or dig in.

To use such a bit, place it in a carpenter's brace in the usual way, punch or drill a pilot hole in the metal at the exact centre of the desired hole, then insert the central pin of the bit in the pilot hole and rotate the bit after lubricating it with paraffin oil. If used with reasonable care, quite a number of holes can be drilled before the bit will need re-grinding.

Holes about $\frac{3}{16}$ inch to about 2 inches diameter can be punched out with a wad punch, or a tinman's hollow punch, as shown in Fig. 6. The punch is held upright on the metal, pressed firmly downwards and then given a heavy blow with a weighty hammer — the kinds known as a 2¼-lb. "Mason's Club" or a "hand sledge" are the best, but any heavy hammer will do. To locate the hole, smear some whiting on the metal, allow it to dry, then describe a circle with pencil compasses, making the circle a shade larger in diameter than the hole so that the punch can be placed just within the pencil circle.

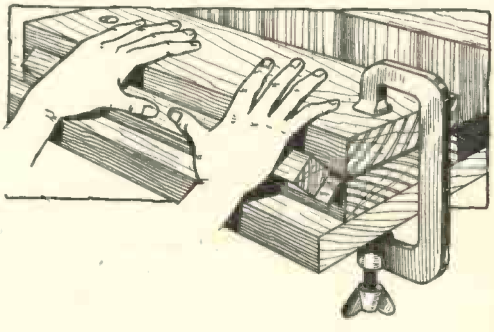


Fig. 9.—Turning a Flange on a Sheet.

The metal is clamped to the bench between two hardwood blocks, the overhanging part is pressed downwards and inwards to form the flange.

Drilling Aluminium

The best drills to use for aluminium work are the straight-fluted type as shown in Fig. 7, especially when used at high speed and well lubricated with turps or paraffin.

Twist drills, as normally ground, have a tendency to run, but this can be remedied by grinding the cutting edges without front rake.

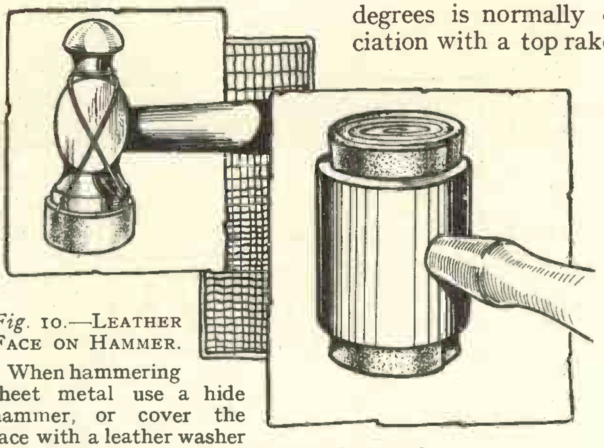


Fig. 10.—LEATHER FACE ON HAMMER.

When hammering sheet metal use a hide hammer, or cover the face with a leather washer as here shown to prevent bruising the metal.

A small hand or breast drill is suitable for most work; great pressure is not needed to make the drill cut, but when drilling deep holes back out or withdraw the drill from time to time to keep it free of chips.

Turning

Some care is needed when turning aluminium in the lathe, as it has a tendency to make the tool drag and tear up the surface.

Secrets of success are to use a high-machining speed—somewhere about 600 feet per minute is a fair average.

All the tools should have a keen edge—obtained by rubbing on an oilstone. A clearance angle of between 15 and 20 degrees is normally correct in association with a top rake of 5 degrees.

The feed may be rather heavier and faster than when working on brass, grooving tools should have about 2 or 3 degrees side clearance.

Milling Aluminium

One of the chief difficulties when milling aluminium is to make sure the chips are clearing away sufficiently quickly. The correct treatment is to use plenty of lubricant and to arrange matters so that it flows quickly on to and away from the work and washes the chips away. Soapy water is effective, but leaves the work with a dull surface, whereas paraffin produces a more glossy finish. Several brands of cutting compound—or lubricant—give excellent results.

All milling cutters should have sharp square-cornered teeth, well spaced and kept in perfect order by honing with an oilstone slip. Cutting speeds when milling should be about 325 feet per minute.

Filing and Scraping

New or clean fresh files give best results on aluminium, the one thing to guard against is clogging of the teeth. To ensure good work, the file teeth must be kept free and open, the least suggestion of clogging

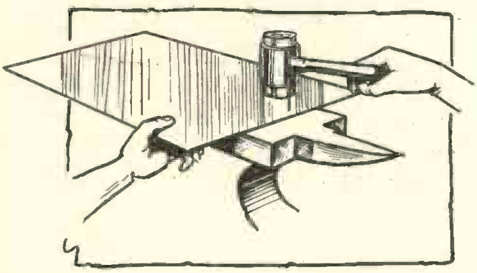


Fig. 11.—PLANISHING HAMMER AND ANVIL.

Aluminium sheets can be flattened by hammering with a planishing or hide-faced hammer on a bright-faced anvil.

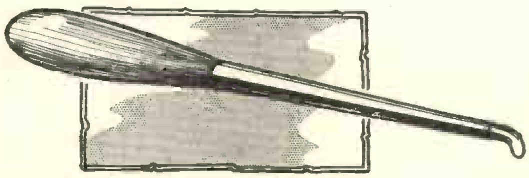


Fig. 12.—BURNISHING TOOL.

Rubbing this agate burnisher backwards and forwards over the metal while lubricated with olive oil imparts a remarkable gloss.

should be dealt with at once by clearing the embedded matter from the teeth with a wire brush or with a pointed brass rod.

French chalk, if rubbed on the file at frequent intervals, helps to prevent clogging, but most can be done by correct manipulation of the file.

Do not exert more downwards pressure than is necessary; use a brisk forward cutting movement and lift the file quite free of the work on the return stroke. The file must cut, it must not be rubbed backwards and forwards or it will inevitably clog and spoil the work.

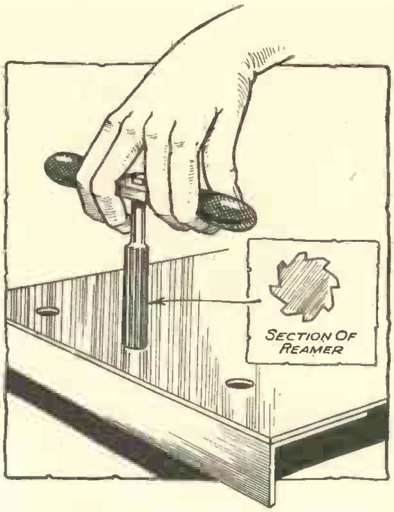


Fig. 13.—Reamering a Rivet Hole.

Perfect alignment of rivet holes is essential for good joints, and this is best assured by reamering the holes.

Pressing

Sheet aluminium can easily be pressed or drawn into shapes such as the shields for valves and coils. When a comparatively small number are needed, and the work is not too large, they can be "pressed" in a fly-press or even formed by hand with the aid of a cast-iron die and a soft mild steel punch, the latter driven home by means of a heavy hammer.

Spinning Aluminium

An excellent way of making a number of special components of circular section is to "spin" them in an ordinary metal-turning lathe.

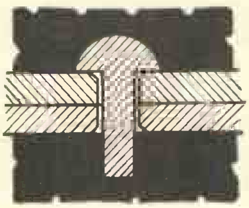


Fig. 14.—First Stage of Riveting.

Enlarged sectional view showing rivet in place with tail protruding and clearance in the hole.

The essentials of a suitable rig-up are shown in Fig. 8, which will sufficiently illustrate the method. First of all a wooden "former" has to be made, and this must correspond in external shape and size with the internal shape of the metal part to be spun.

The former is chucked in the lathe and a disc of aluminium centred against it and held in place by a block called the "follower" on the tailstock, or by a screw or bolt if a central hole is permissible.

A wood or metal block is then bolted to the lathe bed or to the saddle of the slide rest and is provided with several pegs. The spinning tool is a length of mild steel with a ball- or spoon-shaped end, perfectly smooth and constantly lubricated with vaseline.

A handle about 2 feet long is firmly fixed to the metal tool and the lathe set in motion.

The spinning tool is used in the manner of a lever, with one of the pegs on the blocks as the fulcrum and the disc pressed against the wood former. Some amount of practice is necessary to acquire the knack of forcing the rotating disc firmly against the former.

The best speeds are about 1,500 r.p.m. for articles about 4 inches diameter and about 1,000 r.p.m. for larger pieces.

The metal sheet must be thin and soft; if necessary it must be annealed by heating to a temperature of 650° F. and allowing it to cool slowly.

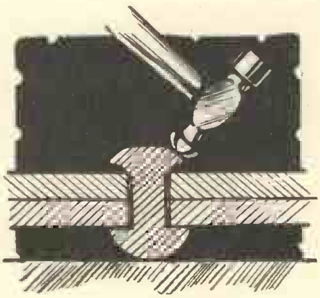


Fig. 15.—Second Stage of Riveting.

This enlarged sectional view shows the rivet expanded in the hole and the ball peine of the hammer forming the head.

Flanging and Bending

Simple right-angle bends can be formed on sheet aluminium in a sheet metal-workers' tool, called an angle-bender, but in the absence of any such equipment the best plan is to clamp the sheet metal firmly between two stout strips of hardwood or metal.

Place the clamps so that one edge comes exactly along the line of the bend, then place a block of wood on the projecting part of the metal as in Fig. 9 and press it bodily downwards with an inwards bending movement.

Endeavour to turn the metal over evenly and avoid buckling. Finish off by hammering on the wood block to force the metal to the correct shape.

If any corrections have to be made afterwards, rest the sheet on a suitable anvil or "bick iron," and with light blows hammer the metal to shape. Use a broad-faced hammer, in the absence of a planishing or repoussé hammer a common shoemaker's hammer comes in very handy. The great thing to avoid is bruising or indenting the metal. A hide-faced hammer, as in Fig. 10, is most useful and prevents bruising the metal. A practical expedient is to fasten a leather washer on the face of an ordinary hammer.

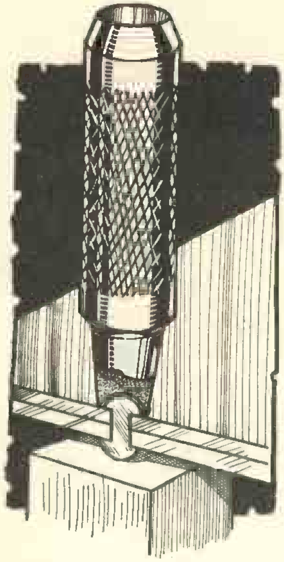


Fig. 16.—Finishing the Rivet.

Showing how the hollow punch is used to shape the rivet head and close it firmly against the metal.

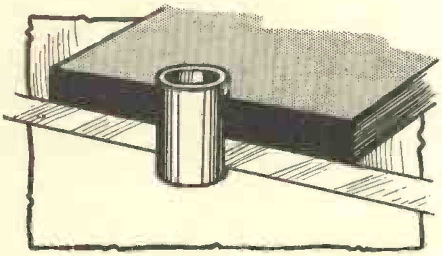


Fig. 17.—Tubular Rivet.

Here is shown the first stages in closing a simple tubular rivet, useful for fixing insulating material to aluminium sheets.

Planishing

A sheet metal chassis only looks well when it is quite flat and smooth, conditions which are met by using a specially-rolled sheet or by the processes known as planishing and burnishing.

Planishing consists in so hammering a sheet of aluminium that any buckles or deformities are removed and the sheet thereby flattened.

The only tools needed are a bright-faced anvil and a planishing or hide-faced hammer (Fig. 11); both must be scrupulously clean and well polished.

The essential principle of the work lies in the fact that when sheet metal is hammered the metal expands superficially at the expense of its thickness; the amount of this expansion and its probable effect on the sheet has to be estimated before striking a blow.

The blows should be of a light, free, or "bouncing" nature, and the hammer face must of course fall flat on the work.

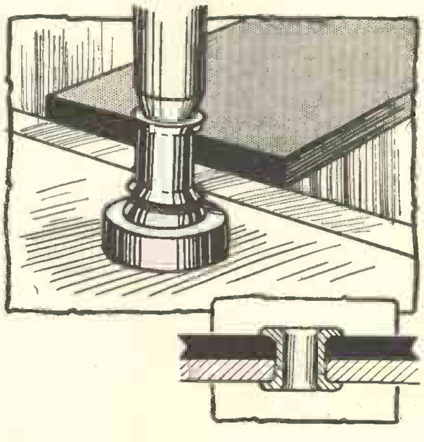


Fig. 18.—Turning the Rivet with a Punch.

The lower end of the rivet rests on a spherical-ended block, the upper end is spread outwards by the punch. (Below).—Sectional view showing how the rivet is expanded and turned at each end.

Suppose, for example, the sheet is "tight" in the centre and "loose" at the edges, that is to say, the sheet cannot lie flat because the middle is relatively too small for the edges.

Obviously, therefore, the remedy is to planish or hammer the centre part only until it has been sufficiently stretched to lie flat.

More often than not a flat sheet is loose at the centre and along the middle of each side, but is tight at the corners, hence the correct procedure is to hammer the corners only. Work a little at a time on each corner until the sheet is flattened.

Polishing

Aluminium can be polished easily with a treadle or power-driven polishing head and the usual buffs and bobs. The first stages are carried out with Trent sand and oil on a leather bob, followed by a greasy tripoli compound on a stitched canvas wheel and the final lustre imparted by buffing with dry lime on a soft mop. The machine should be run at high speed, around 2,500 r.p.m.

Polishing by hand is best attained by first rubbing with clean, old "blue back" emery paper (not emery cloth), moistened with oil, then by buffing sticks charged with powdered pumice, followed by rottenstone and oil. The final process is "rouging up" with rouge and oil, or with whiting and water or with dry lime, all three being used with equal success by different polishers.

Jointing Aluminium

The most practical methods of jointing aluminium for wireless work are by riveting, autogeneous welding and various forms of electric welding.

Screwing, flanging and seaming are of course adopted when necessary, and done in the customary manner.

When bolts, screws or rivets are used, however, it is most desirable they be made of aluminium, otherwise electrolytic action will cause speedy corrosion. The same applies to tubular rivets and other fasteners.

Screwing and Threading

When using taps and dies, always work very cautiously; employ plenty of lubricant and repeatedly back out the tap or die to clear the chips. Paraffin, lard oil, turpentine and soapy water are reliable lubricants.

Riveting

Two items must be studied when riveting aluminium. These are: first, always to use aluminium rivets; and, secondly, to allow sufficient clearance in the rivet hole to allow the rivet to expand and fill the hole without distorting the sheet.

Rivet holes should preferably be reamered, as in Fig. 13, while the two parts are in position to ensure correct alignment, and the edges of the holes should be very slightly countersunk to remove any roughness that might tend to cut the rivet head.

The snap or spherical-head rivet (as in Fig. 14) is the best general form to use; its length should be such that the tail—or part that protrudes beyond the joint—is one and half times the diameter of the rivet. Thus a $\frac{1}{8}$-inch diameter rivet should protrude $\frac{3}{16}$-inch to allow for forming the head with a "snap" punch.

When "closing" the rivet, rest the head firmly on an anvil or other heavy hard surface (as in Fig. 15), and with a light ball peine hammer strike light, sharp blows, first on the centre of the tail, to spread the middle of the rivet, then around the edge to spread and turn the metal. Finally shape it neatly as in Fig. 16, with a snap or hollow punch.

Tubular Rivets

Rivets in the form of eyelets (as shown in section in Fig. 17) are often seen on wireless chassis, and are used to secure a sheet of insulating material or other pieces. Here, again, the rivet should be of aluminium, otherwise electrolytic action will corrode the joint. Such rivets are very easy to fit; they can be closed with a punch and die (as in Fig. 18) or with an ordinary shoemaker's eyelet punch pliers.

An advantage of the tubular rivet is the large bearing surface, and, on occasion, it serves for the passage of an insulated connecting wire to a component beneath the chassis.

HOW TO MAKE A VALVE AND SET TESTER

By H. E. J. BUTLER

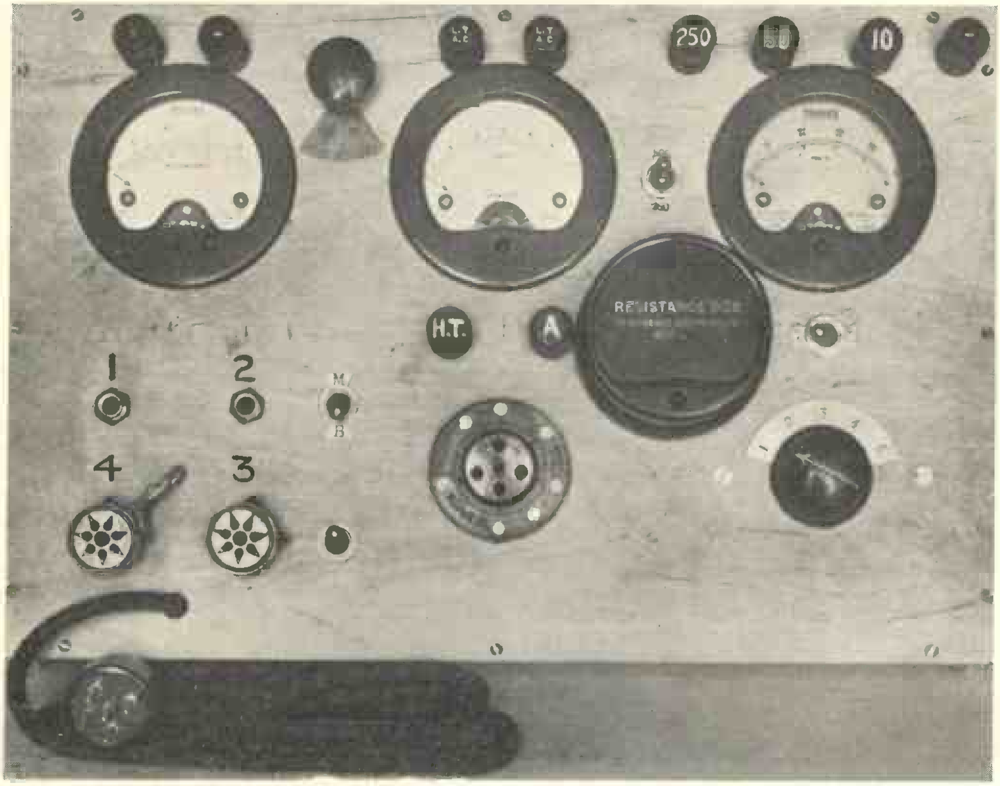


Fig. 1.—The Finished Testing Set.

THIS valve testing set enables the operating conditions of valves to be measured, without the use of batteries, provided that the set to which they belong, is available. It also permits instant fault location in a defective receiver.

The testing set, which is suitable for battery, D.C. and A.C. mains valves, consists essentially of three measuring instruments with a valve holder and a flexible cord having at its end a plug similar to the pin base of a valve. The overall size is 14¾ by 9¾ by 4½ inches.

Parts Required

The parts required, with the exception of the voltmeter switch, are as follow:—

1 voltmeter, moving iron, 0–7·5 volts, flush type	*Ferranti.*
1 voltmeter, moving coil, 1,000 ohms per volt, 0–10–50–250, flush type	*Ferranti.*
1 milliammeter, moving coil, 0–7·5–30–150, flush type	*Ferranti.*
1 resistance to increase volt range to 500 . .	*Ferranti.*
3 closed circuit jacks J.6 .	*Bulgin.*

2 telephone jack plugs P.16 . *Bulgin.*
2 toggle single pole change-over switches S.81 . *Bulgin.*
1 toggle double pole change-over switch S.89 . . *Bulgin.*
1 Q.M.B. switch S.80 . . *Bulgin.*
1 Kabi 3 position single-way Switch . . . *Gurney.*
10 terminals, non-rotating names Type B . . *Belling-Lee.*
Glazite and 5-way cord.
Valve holder, 5 pin . . *Benjamin.*

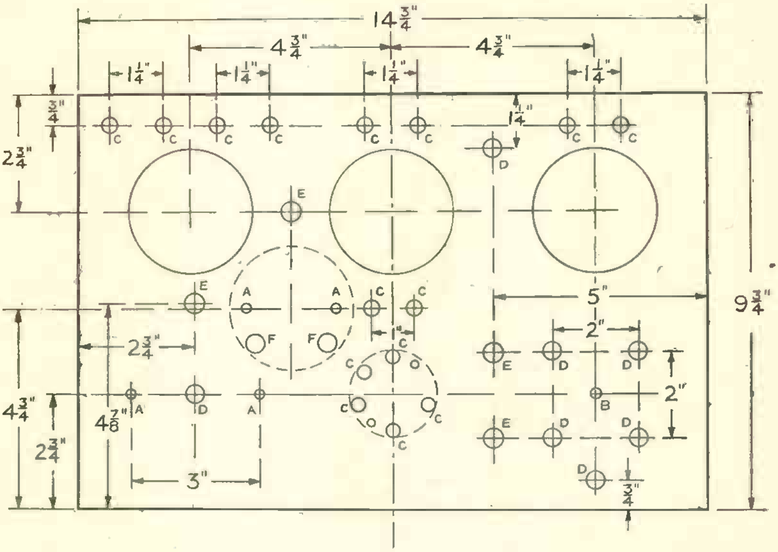


Fig. 2.—A Working Drawing of the Panel Drilling, as seen from Underneath.

The size of the holes are as follows :—A, $\frac{5}{32}$ inch ; B, $\frac{3}{16}$ inch ; C, $\frac{5}{16}$ inch ; D, $\frac{3}{8}$ inch ; E, $\frac{15}{32}$ inch ; F, $\frac{7}{16}$ inch.

5-pin plug P.3 . . . *Bulgin.*
5-4 pin adapter G.R.2 . *Bulgin.*
Approximate cost, £10.

What the Instruments do

The moving iron voltmeter is used for measuring the voltage across the filaments or heater of the valve on test. This type of instrument is primarily intended for A.C. measurements, but is sufficiently accurate on D.C. also, so that this instrument is made to serve the double purpose of taking the heater voltage on A.C. valves and filament volts on battery type valves.

The three-range moving coil voltmeter must be of the 1,000 ohms per volt type or inaccurate readings are obtained both on grid and plate voltage measurements. This instrument is arranged to read separately the voltage between the cathode, or filament, and any of the other electrodes of any type of valve which does not require more than 500 volts H.T. The voltage range may be increased to any desired value by including suitable multipliers. The current taken by this instrument, for full-scale deflection is 1 milliampere, which does not introduce any appreciable error, except in grid bias and screen grid voltage measurements. The unavoidable sources of error due to the power taken by the measuring instruments are dealt with later.

The milliammeter has three ranges which are controlled by a three-point switch. The lowest range is suitable for high frequency and detector valve measurements, while the 30 and 150 milliampere ranges are used for amplifying and power valve currents.

The filament current is not measured because most valves are designed to work at a definite voltage and not at a particular current, so that there is no point in measuring it.

The Purpose of the Testing Set

The main purpose of the testing set is to take the voltage and current readings on valves under the exact conditions which they are working in a receiver, without disturbing any of the wireless set connections. The set is designed so that the meters can be used individually for other purposes by connecting to the terminals at the top of the set.

The Panel

The panel is made, preferably, from good insulating material such as ebonite, paxolin, or bakelite. Wood may be used, however, if the jacks and terminals are provided with ebonite insulating bushes. The Belling-Lee terminals, which are specified, have insulating bushes, and it is necessary only to place an insulating washer under the fixing washer to secure perfect isolation from a wood panel. A wood panel may be preferred for its cheapness and ease of working. A metal panel is not safe and must be avoided. The panel must not exceed ¼ inch in thickness, because the jacks and switches are designed for panels only up to ¼ inch thick.

Making the Panel

A drawing of the finished panel is shown in Fig. 2. The size and layout is proportioned for a box or supporting rebate not exceeding ⅜ inch thick. If the box or rebate is made thicker, the overall size of the panel must be increased proportionally or the terminals will foul the side of the box.

After the panel has been cut to size and squared up, the holes are marked off on the back in accordance with Fig. 2. Do not cut any holes until they have all been marked off or the job will be unnecessarily difficult. Pencil marking must be avoided, because a pencil line between two holes may result in a leak.

How to Drill the Holes

When drilling the holes place a flat piece of wood beneath the panel to prevent the holes splintering on the face side as the drill breaks through. The terminal holes have a small nick filed in them after drilling, to register with the keys on the terminal bush mouldings. A nick is similarly made in back of the large meter holes, in accordance with the template supplied with the meters.

The holes for the valve holder are marked off from the part itself after the screws have been removed. The position of the voltmeter resistance box is marked off from the maker's template, which is the same as for Ferranti 2½-inch projecting type meters.

The finished panel is shown in Fig. 3.

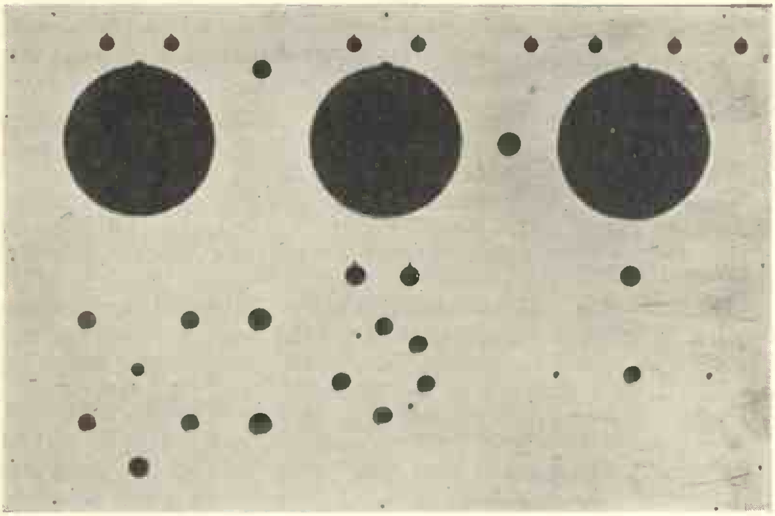


Fig. 3.—THE FINISHED PANEL AS SEEN FROM THE TOP.

THE VOLTMETER SWITCH

The purpose of the voltmeter switch is to connect the voltmeter to the various electrodes of the valve in turn when making tests. It not only changes the electrode connection but also the voltage range of the meter, although it is not possible to obtain complete control of the voltmeter by this switch alone without undue complication which would be beyond the scope of the average constructor.

The top view of the switch is shown in Fig. 4 and the underside is shown in Fig. 5.

Materials required for the Switch

The materials required for constructing the voltmeter switch are as follow :—

Ebonite, bakelite or paxolin, $3\frac{1}{2}$ by 3 by $\frac{3}{16}$ inch thick.
18 5BA contact studs, $\frac{1}{4}$ by $\frac{1}{4}$ inch, with nuts and washers.
No. 18 S.W.G. hard nickel silver, $1\frac{5}{8}$ inch diameter.
2 $\frac{3}{8}$ inch 26 t.p.i. brass lock nuts.
No. 20 S.W.G. hard phosphor bronze, 3 by $\frac{5}{8}$ inches.
1 $\frac{3}{16}$ inch bronze or steel ball.
2 4BA nuts and washers.
6 inches of $\frac{5}{8}$-inch diameter brass.
3 inches each of $\frac{5}{16}$ inch diameter, $\frac{3}{8}$ inch diameter and $\frac{1}{2}$ inch diameter brass.
1 knob and scale.

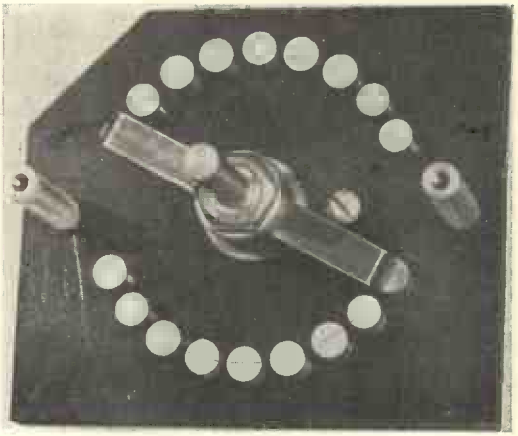


Fig. 4.—The Top View of the Voltmeter Switch.

Showing the layout of the contact studs and the supporting pillars.

Making the Switch

The first stage in the construction of the switch is to mark off the contact panel. To do this, find the centre of the ebonite first and then scribe a circle with the dividers set at $1\frac{1}{8}$ inch radius. The two centre lines on the ebonite are then marked as shown in Fig. 6. The next stage is to mark the equidistant centres of the two sets of nine holes for the contact studs. If 4BA contact studs are used in place of the 5BA studs specified, the holes are drilled with No. 26 instead of with a 30 drill, as shown in Fig. 6. When the contact panel has been drilled the corner is cut off as shown in Figs. 5 and 6, if the 500-volt multiplier is to be included in the set, if not, the corner may be left on.

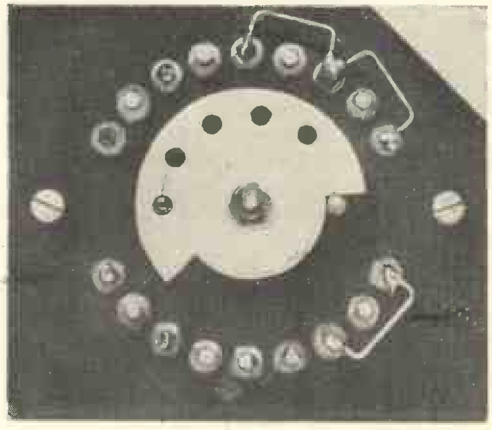


Fig. 5.—The Underside of the Voltmeter Switch.

Showing the catch plate.

The Spindle

The next parts to make are the spindle with its sleeve, bush and washers. These are shown in Fig. 7. The exact dimensions of these parts do not matter so long as they are correctly proportioned. The distance from the underside of the contact panel to the catch plate should not be less than $\frac{9}{16}$ inch. The switch is secured to the panel of the set by two pillars 1 inch long and $\frac{5}{16}$ inch diameter, which are shown in Fig. 4. These pillars have 4BA tapped holes in each end. Although the switch has nine possible positions only five are used. It is necessary to have a dead intermediate position between each to prevent shorting two electrodes of the valve under test.

Obtaining Proper Registration

The proper registration of the switch arm on the wired studs is ensured by the catch plate which is shown in Figs. 5 and 8. Between the contact panel and the catch plate is a tube containing a spring and steel ball. This tube is made from $\frac{3}{8}$ inch diameter rod with $\frac{1}{8}$ inch of 4BA thread in one end, which serves to screw it to the base. The rest of the rod is drilled out with a No. 12 drill to clear the ball and spring. There should not be more than $\frac{1}{16}$-inch play between the catch plate and the ball housing. The catch plate also acts as a stop plate to prevent the switch arm from being turned off the end contacts. The dimensions of the portion cut out to act as a stop shown in Fig. 8 hold good for a $\frac{5}{32}$-inch diameter stop pin. Unless the ball spring is made very strong it is not essential to steady pin the switch arm and the catch plate to the spindle, although it is safer to do so. The spring should be made from ·015–·018 steel spring wire.

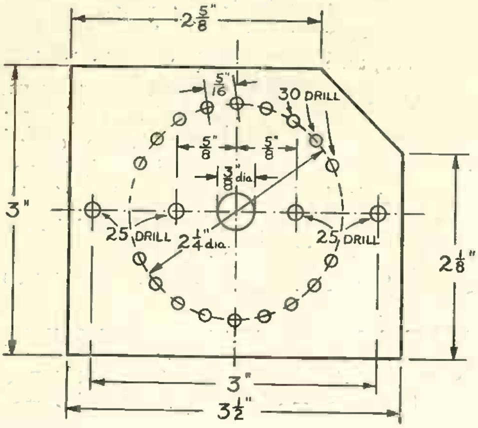


Fig. 6.—Working Drawing of the Contact Panel of the Voltmeter Switch.
The material is $\frac{3}{16}$ inch ebonite or bakelite.

The Circuit

The wiring diagram of the testing set as seen from the underside of the panel is shown in Fig. 9. The 5-pin plug which is attached to the end of a 5-way flexible cord is shown in the bottom right-hand corner of the diagram. The main principle of the operation of the testing set is as follows:—

When the plug is inserted in the wireless set valve holder, the valve holder on the testing set is then in parallel with it. The valve which has been removed from the valve holder in the receiver is plugged into the holder on the testing set. The jacks, the two contacts of which are closed when the plug is removed, are arranged so that the milliammeter can be inserted in the various electrode circuits in turn. The voltage readings are taken by rotating the knob of the voltmeter switch which is located below the voltmeter as shown in Fig. 1.

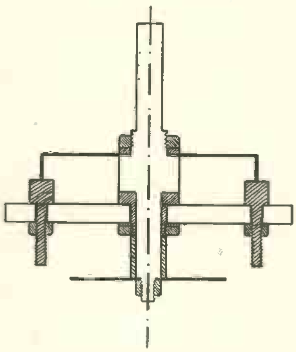


Fig. 7.—Sectional Drawing of the Switch.
Showing the construction of the spindle and contact blade.

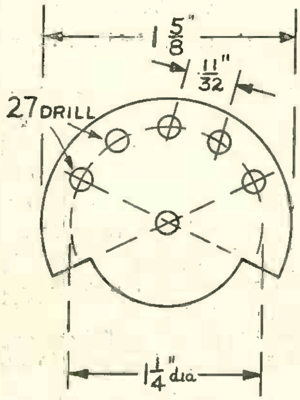


Fig. 8.—Working Drawing of the Catch Plate of the Voltmeter Switch.

THE CIRCUIT IN DETAIL

The two filament or heater pins and the grid pin of the 5-pin plug are wired directly to the corresponding pins of the valve holder on the testing set. The anode pin and the centre pin are wired to jacks, so that current readings may be taken in these circuits.

No. 1 Jack

The anode current of screen grid valves and control grid of A.C. pentode valves is measured by plugging into jack No. 1. When either of these types of valves is under test the terminal on the valve is connected to the anode terminal above the valve holder and the wire which is normally connected to the valve in the receiver is extended to the H.T. terminal.

Figs. 10 and 12 show the part of the valve circuit in which jack No. 1 is wired, when either a battery screen grid or AC/screen grid valve is on test.

No. 2 Jack

The anode pin is connected to No. 2 jack so that when the jack plug is inserted in this plug, anode current readings are measured by the milliammeter. In A.C. screen grid valves this jack reads the screen or screen grid current and not the anode current. This jack is used for taking current measurements on all types of receiving valves, as shown in the circuits Figs. 10–14.

No. 3 Jack

Wired in parallel with No. 4 jack, but connected in opposite polarity to it, jack No. 3 is used for measuring the total current in the cathode circuit of any type of indirectly heated valve. This is useful when it is desired to know the current passing through the self-biasing resistance which is usually connected in the cathode lead. The position of this jack in the circuit of the testing set is shown in Figs. 10 and 11. When using jack No. 3 it is essential to insert a spare plug in jack No. 4, otherwise no reading is observed, because the contacts of jack No. 4 short those of No. 3, which is in parallel with it. Fig. 1 shows the milliammeter plug in jack No. 4 with the spare jack in No. 3.

No. 4 Jack

No. 4 jack is intended for taking current measurements in the control grid circuit of a 5-pin battery or directly heated type of pentode valve, because this jack is connected in the centre pin circuit. This jack is not used for taking measurements of any other type of valve.

It is necessary to insert a spare jack in No. 3 plug when using No. 4 for taking readings, for the same reason as explained under the heading of No. 3 jack. The position of this jack in the circuit of the battery or directly heated pentode is shown in Fig. 14.

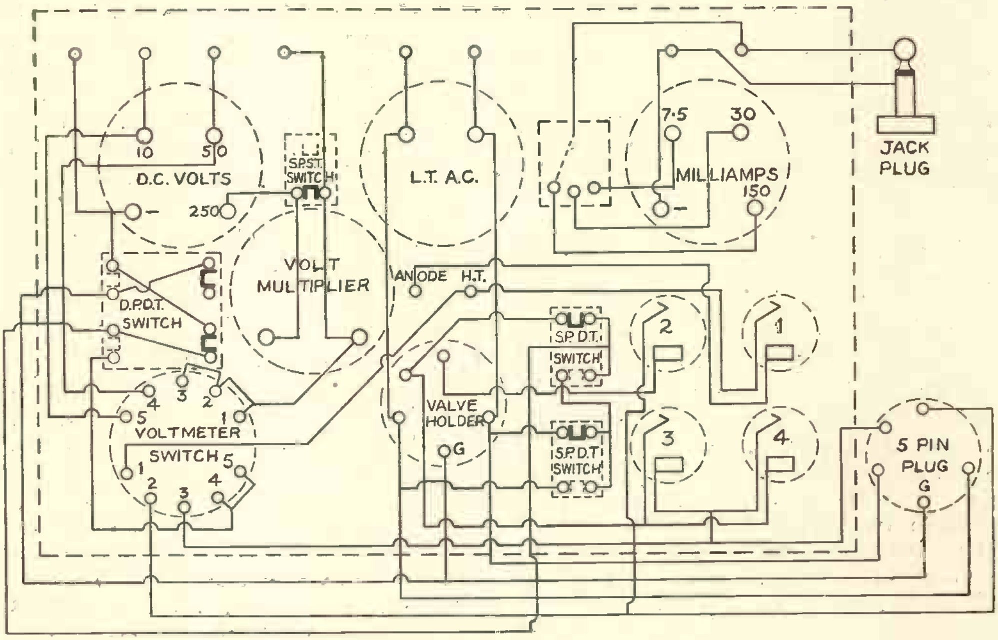


Fig. 9.—The Complete Wiring Diagram of the Testing Set which is Fully described in the Text.

The two contacts of the jacks are short-circuited when the plugs are withdrawn.

The Switches

There are four miniature toggle and two rotary switches which are used when taking the various readings. The exact purpose of each will be explained under a separate heading.

Mains-Battery Switch

Situated between the jacks and the valve holder, the upper single pole double throw (S.P.D.T.) switch controls the negative connection of the voltmeter, when anode, grid and screen voltages are being taken. The wiring is shown in Figs. 15 and 20. The negative terminal of the D.C. voltmeter is connected, *viâ* another switch, to the common contacts of the S.P.D.T. switch. When the switch is in the " M " position (Fig. 1) the D.C. voltmeter negative is connected to the cathode pin of the valve, so that voltage readings are taken between this point and the anode, grid and screen. With the switch changed over to the " B " position (Fig. 1) the voltmeter negative is connected to the common contacts of the lower S.P.D.T. switch, for taking voltage readings between the screen, anode and grid of battery or directly heated A.C. valves.

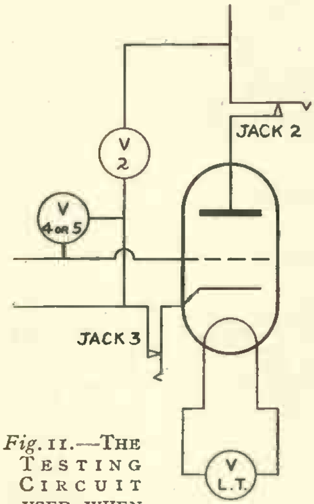


Fig. 11.—The Testing Circuit used when an A.C. Triode is on Test.

Battery Filament Switch

The lower of the two S.P.D.T. switches enables voltage readings to be taken from either side of the battery-heated filament. This is more valuable when taking grid bias measurements. In some receiving circuits the filament volts will add to the grid volts in one position of this change-over switch, whereas the battery volts subtract from the H.T. voltage readings in one position of the switch, when negative H.T. is common with negative L.T. This switch has no purpose when taking measurements on indirectly heated valves or directly heated A.C. valves.

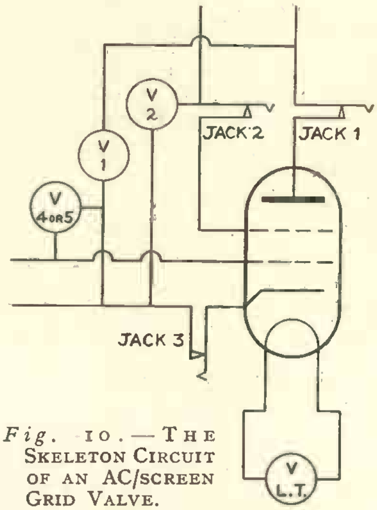


Fig. 10.—The Skeleton Circuit of an AC/Screen Grid Valve.

Showing the position of the various testing points when using the testing set. V1, 2, 4 and 5 refer to the voltmeter switch positions and indicate the actual positions of the voltmeter in the circuit. V–L.T. is the A.C. voltmeter. When an AC/pen is on test V1 and V2, J1 and J2 are transposed.

H.T. Volts-Grid Volts Switch

This switch, a double pole double throw (D.P.D.T.) type, is located between the 5-point voltmeter switch and the D.C. voltmeter as shown in Fig. 1. The wiring of it is shown in Fig. 9. The purpose of this switch is to connect the cathode, or filament, of the valve to a suitable positive terminal on the D.C. voltmeter at the same time connecting

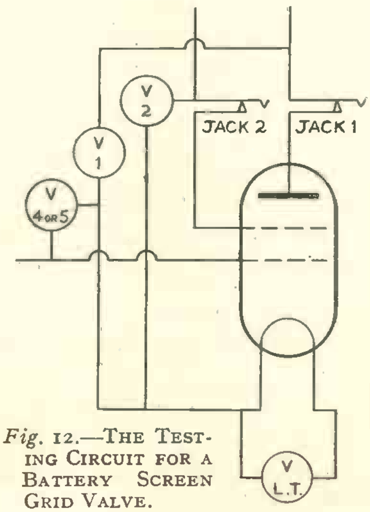


Fig. 12.—The Testing Circuit for a Battery Screen Grid Valve.

the grid of the valve to the voltmeter common minus. The positions of the switch contacts when grid bias readings are to be taken are shown dotted in Fig. 9. With the switch contacts in the position shown by thick lines the voltmeter is set for taking anode and screen voltage readings, that is, switch to the right as in Fig. 1.

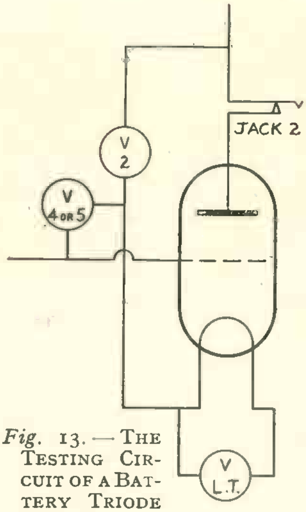


Fig. 13.—The Testing Circuit of a Battery Triode Valve.

250–500-Volt Range Switch

The switch situated between the D.C. and A.C. voltmeters is simply to short, or place in circuit, the extra 250,000-ohm resistance box. When this switch is "down" the resistance is short-circuited, thus giving voltage readings up to 250. When the short circuit is removed, readings up to 500 volts are read × 2 on the 250-volt scale.

The Voltmeter Switch

With the 5-position voltmeter switch at No. 1 the two contacts 1 and 1, Fig. 9, are joined. In this position voltage readings are taken on the anodes of A.C. and battery screen grid and control grid of indirectly-heated A.C. pentode valves.

With the voltmeter switch in No. 2 position the anode pin of the valve is connected to the voltmeter, which gives anode voltage readings for triode valves, A.C. and battery pentodes, screen grid voltages for A.C. and battery screen grid valves. No. 3 position of the voltmeter switch is used only for voltage readings on the control grid of battery or directly-heated pentode valves. With the switch in this position the voltmeter gives no reading on indirectly heated valves because, as is seen from Fig. 9, both positive and negative of the voltmeter are then connected to the centre pin or cathode.

Before grid bias readings can be taken the switch immediately below the voltmeter is changed over, as explained under the heading of "H.T. Volts-Grid Volts Switch." Position 4 gives grid bias readings on the 50-volt scale, while position 5 measures grid volts up to 10. If through an oversight the D.P.D.T. switch is left in the grid bias position while the switch is in positions 1, 2, or 3, voltages are read between the grid and other high potential anodes.

These readings are erroneous and have no value, because the current which is thereby created in the grid circuit either lowers the grid bias or applies a positive one.

The Milliammeter Switch

The milliammeter switch enables either of the three scales to be used with the jack plug in any of the jacks. The switch transfers the positive meter connection in turn to each of the three positive meter terminals. This switch is always left in the 150-milliampere position so as to obviate the possibility of overloading the meter when first switching on to test. It is a good plan to put a spring on the switch arm so that the switch can only be held in the two lower range positions and flies back automatically to the 150 milliampere scale position after a low range test. This meter is, however, provided internally with a replaceable fuse which effectively prevents damage to the meter.

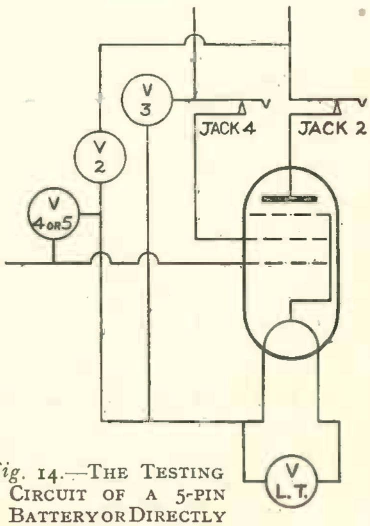


Fig. 14.—The Testing Circuit of a 5-pin Battery or Directly heated A.C. Pentode Valve.

MOUNTING THE PARTS

The first stage in the assembly of the panel is shown in Fig. 16. The D.P.D.T. switch must be partly wired before being screwed down, or else this switch is wired in position before the voltmeter switch is fixed. The valve holder has to be altered if the Benjamin type is used as shown in Fig. 1. The five terminals are unscrewed and in their place are put five 1½-inch long 6BA or 5BA screws to project below the baseboard.

The indicating tabs of the switches which are clamped under the ferrules have to be altered for two of the switches. The 250–500 volt switch is stamped 500 and 250 on the reverse side of the tabs, 500 being marked in the off position of the switch. The figures are filled in with black paint to make them distinguishable. The mains - battery change - over switch is stamped with "M" and "B" on the plain side of the indicating tabs, instead of the H.T.—L.T., which is supplied. The engraving on the D.P.D.T. switch can be used without alteration although H.T.—G.B. may be marked on the plain side of this tab if desired instead of the H.T. and L.T. markings supplied.

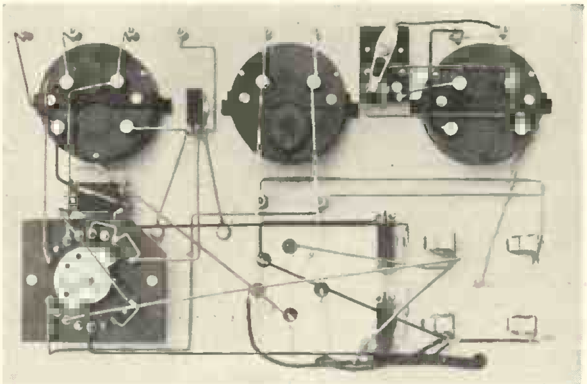


Fig. 15.—The Completely Wired Testing Set
The wiring is done with coloured Glazite.

The Terminals

When the terminals are mounted on a wood panel, ebonite washers are placed under the clamping washers so as to completely insulate them from the wood. There is no need to provide bushes in the panel because the terminals themselves are constructed with moulded bushes. Although the terminal clamping nuts must be securely tightened, do not overdo the clamping or the terminal bases will be split.

The Toggle Switches

The miniature switches are first tightened with the fingers by means of the threaded ferrules above the panel. They are then finally clamped up tightly by the back nuts below the panel. These nuts fit a cycle cone spanner, which is sufficiently thin to pass between the switch and the baseboard when the nuts are screwed right back.

The Meters

The three meters, after being tried in their holes to check the sizes, are put on one side in their boxes while the remainder of the assembly and the bulk of the wiring is done.

The Milliammeter Switch

Although a standard 3-point switch is procurable, this switch may be simply constructed from an old type of filament rheostat as shown in Figs. 17 and 18. Fig. 17 shows an Ormond 30-ohm rheostat taken from a dismantled receiver using ·06 ampere dull emitter valves, which are now obsolete. The part of the rheostat used is the bush contact arm and part of the bending in which the bush is riveted. The top of the switch is shown in Fig. 18. It will be seen that the bending is cut away to a convenient diameter and the bush is passed through a ½-inch hole in a piece of ¼-inch ebonite. A good method of obtaining a connection to the contact arm is to clamp a tag under the screw which retains the arm and solder to it a flexible wire as shown in Fig. 19.

THE WIRING

The most important part of the work is the wiring. Needless to say, all connections in an electrical testing set must be

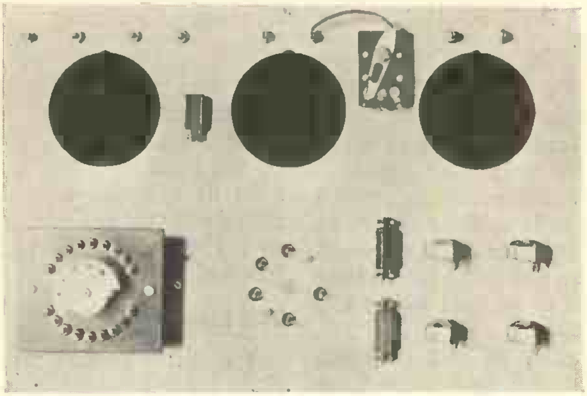


Fig. 16.—The Partly Assembled Panel.

beyond doubt because a breakdown in the testing set may lead to incorrect conclusions when using it.

The wire used for most of the connections in the set shown in the photographs is coloured Glazite. The short wires for the change-over switch interconnections are bare tinned 18 S.W.G. copper. These connections are very short and are not likely to give rise to a fault.

The First Step

The first part of the wiring is to make the short bare connections between the three change-over switches. These connections between the two S.P.D.T. switches are shown in Fig. 20. The connections to the switch tags are made with neat wire loops just big enough to pass the No. 8 B.A. clamping screws. The loops must fit the screws closely or they will not go between the side lugs of the tags. If soldered connections are preferred at these points the screws are removed and the tags tinned before mounting the switches.

The Second Stage

When the small switch connections have been done the 5-point voltmeter switch is screwed into position.

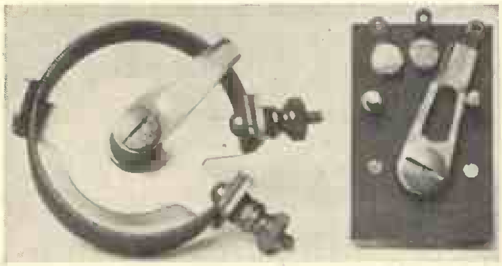


Fig. 17.—The Underside of the Milliammeter Switch and the Rheostat from which it was Adapted.

The colour scheme suggestion for the wiring is as follows :—

- Red : All H.T. wires from meter switches and jacks.
- Green : Grid wire and 10–50 volt scale circuits.
- Yellow : Cathode or filament circuits.
- Black : Negative wires and cathode or centre pin leads.
- Blue : Milliammeter positive wires to 3-point switch.

In order to obtain a good connection under the wire clamping nuts of the slotted terminal ends, the ends of the wires are folded over double. If this is not done the nuts shear the wire when properly tightened up. Whether washers are used or not makes no difference.

The Flexible Cord

The ends of the flexible cord below the panel are clamped with a small wire clip to prevent the possibility of any strain on the connections. Beyond the wire clip the outer covering of the cord is removed. After the separate flex leads have been cut to length the ends of the braiding are coated with Durofix and allowed to dry. This preparation is a good insulator, because it is a cellulose preparation and provides a neater finish than cotton bound ends. When the Durofix is hard, clean off the insulation for ¼ inch so that the wires may be soldered. The following are the

Fig. 18. — The Upper Side of the Milliammeter Switch shown in Fig. 17.

connecting points of the 5-way cord :—

Grid pin on plug to grid of valve holder.

Anode pin on plug to upper tag of jack 2.

Cathode pin on plug to lower tag of jack 3.

Heater pins on plug to heater of valve holder.

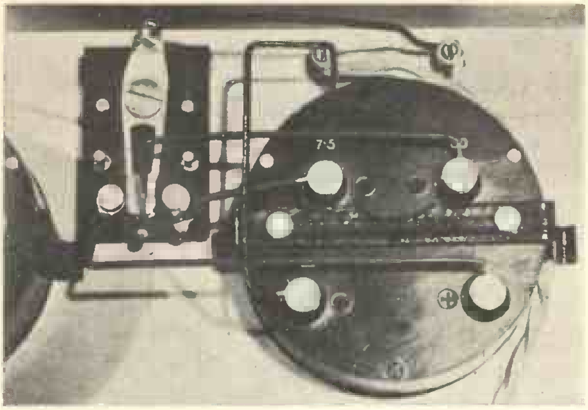


Fig. 19.—THE WIRING OF THE MILLIAMMETER AND ITS SWITCH.

The Meters

The meter wiring, as mentioned already, is left until last to obviate handling the set more than necessary after the instruments are screwed into position. Where there are two wires under the same meter terminal, as for the voltmeters, place a washer between each wire loop as well as one between the head of the screw and the upper wire loop.

Milliammeter Cord

The last part of the wiring is to connect up the flexible cord between the milliammeter terminals and the jack plug above the panel. This cord should be left only just long enough, so as to prevent accidental contact of the plug with any other apparatus which may be near the testing set.

The completely wired set is shown in Fig. 15.

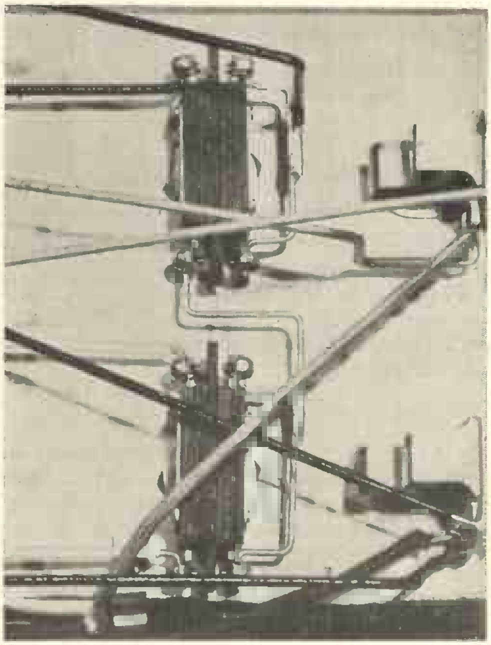


Fig. 20.—DETAILS OF THE WIRING ROUND THE TWO S.P.D.T. SWITCHES.

HOW TO USE THE SET

The first operation in making a test on a valve is to switch off the set and remove the valve in question. The plug adapter from the test set is then inserted in the valve holder of the receiver and the valve put in the valve holder on the test set.

The Normal Position of Switches

Before a test is started, all the switches are left in a position which cannot harm any type of valve or the instruments. The following are the normal or safest positions in which to leave the switches :—

5-point voltmeter switch : Stud 2.

3-point milliammeter switch : 150 M.A. position.

H.T.-grid bias change-over switch : H.T. position.

250-500 volt switch: 500-volt position.

Jack plug : Jack 2.

The position of the two S.P.S.T. switches is immaterial as regards safety.

The 5–4 Pin Adapter

The Bulgin 5-pin plug has a 5–4 pin adapter which it is necessary to use when making tests on 4-pin valves. Four-pin valves include all battery types except 5-pin pentodes.

CURRENT MEASUREMENTS

BATTERY AND DIRECTLY HEATED CATHODE VALVES

Jack	1	2	3	4
Type of valve	Anode m.a. screen grid ×× control grid m.a. pentode 4-pin.	Anode m.a. triode and pentode ×× screen m.a. screen grid.	not to be used	Control grid m.a. pentode 5-pin.

A.C. MAINS INDIRECTLY HEATED CATHODE VALVES

Jack	1	2	3	4
Type of valve	Anode m.a. screen grid and pentode control grid m.a.	Anode m.a. triode and pentode ×× screen m.a. screen grid	Total m.a. cathode circuit	not to be used

VOLTAGE MEASUREMENTS

BATTERY AND DIRECTLY HEATED CATHODE VALVES (B)

D.P.D.T. Switch	H.T.	H.T.	H.T.	G.B.	G.B.
5-position Switch	1	2	3	4	5
Type of valve	Anode volts screen grid ×× control grid volts pentode 4-pin.	Anode volts triode and pentode ×× screen volts screen grid	Control grid volts pentode 5-pin.	Grid volts 50 volts scale all types	Grid volts 10 volt scale all types

A.C. MAINS INDIRECTLY HEATED CATHODE VALVES (M)

D.P.D.T. Switch	H.T.	H.T.	H.T.	G.B.	G.B.
5-position Switch	1	2	3	4	5
Type of valve	Anode volts screen grid ×× control grid volts pentode	Anode volts triode and pentode ×× screen volts screen grid		Grid volts 50 volt scale all types	Grid volts 10 volt scale all types

All mains-type valves require the 5-pin plug alone.

The above tables summarise the switch and plug positions which are used for the various tests.

Precautions

Plugging into jack No. 3 when testing on battery pentode gives a reverse reading on the meter which is not usually detrimental but should be avoided. Similarly a reverse current reading is obtained if jack No. 4 is used when testing on A.C. valve of the indirectly heated type.

Always throw the D.P.D.T. switch to the H.T. position after taking grid bias readings. Do not throw this switch into the G.B. position unless the voltmeter switch is in either position 4 or 5.

D.C. Mains Valves

This set is not suitable for testing indirectly heated mains valves unless the low tension voltmeter in the middle is replaced by one reading up to 50 volts. All the tests, except the heater volts test, may be taken on this type of valve if the low tension voltmeter is disconnected.

Rectifier Valves

Do use this set to take measurements on A.C. mains rectifying valves.

GANGED COIL CIRCUITS

HOW TO MATCH THE COILS FOR USE IN THEM

By L. D. MACGREGOR

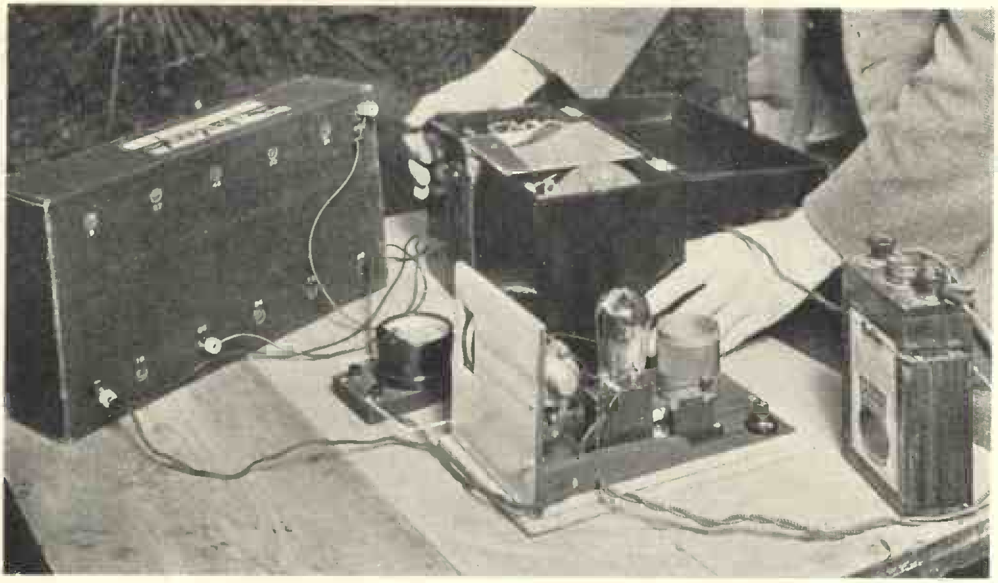


Fig. 1.—Setting Up and Adjusting the Mac-Lachlan Wavemeter.

THE following particulars will be of interest to those who wish to construct their own coils for use in receiving apparatus employing ganged condensers and are desirous of matching the coils as far as is possible. In the following paragraphs one or two methods of achieving this aim will be described and, as far as is possible, apparatus of a simple nature will be employed.

Why Ganged ?

The main reason for ganging is to obtain simplicity of control. Whereas in the earlier type of receivers many tuning condensers, each having its own control knob, were employed, nowadays it is the practice to arrange the tuning condensers in such a manner that one spindle, common to all of them, turns them simultaneously.

The Principle of Ganging

Let us imagine that we have a number of coils, the electrical constants of which are equal, and an equal number of variable condensers so arranged that one spindle will operate all of them. Further, let us assume that these condensers are exactly similar and have the same electrical constants at whatever position they are set. If now we connect a coil to each condenser we will have a number of tuned circuits, which should all tune to a common wavelength, depending upon the amount of capacity which is in circuit. It is on this principle that the present-day ganged receivers are founded.

Variations which are Met with in Practice

In practice, many minor variations are likely to occur. It is extremely difficult

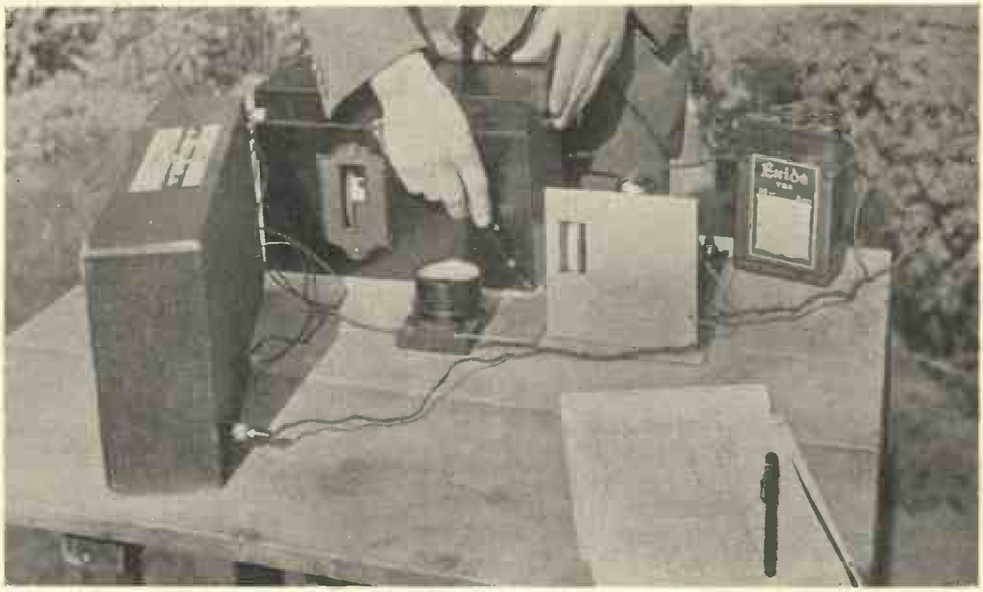


Fig. 2.—Marking Out the Final Positions of the Components.
This should be done so that should anything be disturbed it can be set in place again.

Fig. 3.—Placing a Coil on the Stand.
The stand is necessary so that each coil may occupy exactly the same position as the others.

to produce ganged condensers in which each gang has exactly the same capacity as any other gang. Further, the wiring to each coil is very likely to be different, and small stray capacities, usually termed the self capacity of the wiring, may cause undesirable effects, all of which will tend to make the wavelength of one circuit slightly different from the others, leading to a loss of general efficiency.

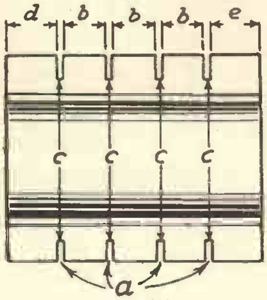


Fig. 4.—Details of the Formers.

If good coils are required the following distances should not vary :— *a*, width of the slots ; *b*, distance between slots ; *c*, diameters at bottom of slots ; *d* and *e*, distance from ends of formers.

Compensating Adjustments in Ganged Circuits

It often occurs that the minimum settings of different gangs in a ganged condenser vary, and to compensate for this effect, and for the self-capacity of the wiring, the makers generally affix tiny variable condensers to each gang. These are known by the name of "trimming condensers." In certain cases further pre-set condensers are placed in parallel across the tuning condensers. This is sometimes done to "swamp" out tiny variations, but more generally to compensate for some capacity effect which is greater than the amount the "trimming condensers" can cater for.

Constructional Points which may Affect the Matching of Coils

Before proceeding to the matching of coils, it is advisable to consider those constructional points which will affect the issue.

It is readily apparent that coils which are constructed exactly alike will be more easy to match than will be coils whose dimensions vary even though the inductance values are nearly the same. Further, there is a special advantage in using coils of the same size in that, assuming the same sized screening covers are used, they may be placed in them after matching and, provided they are all placed in the same relative positions and there is the same amount and kind of metal under each pot, they should not require rematching. On the other hand, coils of various sizes, though possessing the same inductance values outside of the screening pots will, when placed within them, suddenly acquire apparently different values. In this case these coils should only be matched whilst in their containers.

It is proposed to deal first with coils having the same dimensions, and later to add a few hints regarding those of varying sizes.

WINDING THE COILS

The first point under consideration, therefore, is that the shape and size of the coils should be the same. This necessitates the formers on which the coils are wound being alike (Figs. 4 and 5).

If cylindrical formers are to be used, they should be examined for size, thickness and for being oval. It is wise to reject oval formers and those where the thickness varies widely. If ribbed formers are used they should be carefully examined for diameter across the ribs, and should all be the same. If slots are cut in ribbed formers the diameters at the bottom of the slots should be the same, as should be the size of the slots and the distances they are apart.

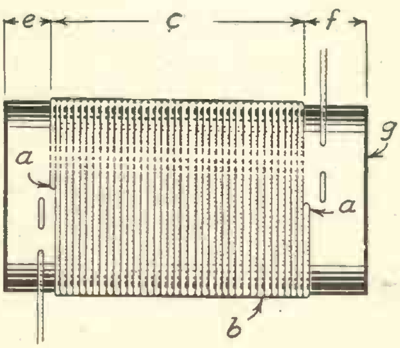


Fig. 5.—Points which should be Noted in the Construction of Coils.

a, starting and finishing ends of all coils to be similar ; *b*, number of turns, wire gauge and covering ; *c*, space occupied by turns ; *e* and *f*, distance from ends ; *g*, former, material, thickness and rotundity of former.

Where to Start the Windings

The windings should start the same distance from the end of each former so that when the coils are placed in pots the windings will be the same height from the metal.

Needless to say, the same gauge of wire and covering should be used for a batch of coils, and the wire should neither be wound on loosely nor stretched.

If the batch of coils be wound from the same reel of wire there is less risk of the wire gauge and covering having altered than if they are wound from different reels of wire.

Failure to attend to these points will result in coils being produced having widely varying inductances and other electrical constants which may not easily or cannot be matched.

If more than one winding is placed on the same former it is advisable to check one winding first before winding on the other winding. For example, if winding a medium-wave coil with reaction, wind on the medium-wave coil first, then the reaction, after checking the first winding.

HOW TO TEST THE COILS

The method employed is a simple one, and consists in tuning the coil under test by means of a variable condenser. This tuned circuit picks up the energy transmitted by a wavemeter and the voltage developed across the tuned circuit is observed by means of a valve voltmeter. Details for constructing a valve voltmeter are given later in this article.

Apparatus Required for Testing

One wavemeter or oscillator.

One valve voltmeter.

One good variable condenser with slow-motion drive and dial.

Suitable supply of H.T. and L.T.

A suitable wavemeter is the MacLachlan station finder, manufactured by Gambrell, Ltd. If a standard valve voltmeter is not accessible, a satisfactory substitute can be easily erected in a few minutes, as it is not essential that the voltmeter be calibrated. The variable condenser should have a capacity of at least ·0005 mfd., and should be of a robust construction, and possess a reasonably large dial. For accurate matching it is essential that there be no "slip," or "play," between the dial and the condenser spindle.

Needless to say, the wavemeter should have suitable coils to cover the wavebands for which the coils have been constructed.

The Principles of the Test Methods

It is known that a relationship exists between wavelength, a given inductance and capacity, and this can be shown graphically, as in Fig. 6. In this sketch the vertical scale is laid out to the square of the wavelengths—that is the wavelength figure multiplied by itself—whilst the horizontal scale from zero to the right shows the scale of the capacity used to tune the coil. The capacity value to the left is in the same scale units as that to the right, and indicates the additional capacity in circuit, other than that due to the tuning condenser. This capacity is the total amount due to wiring and the self capacity of the coil.

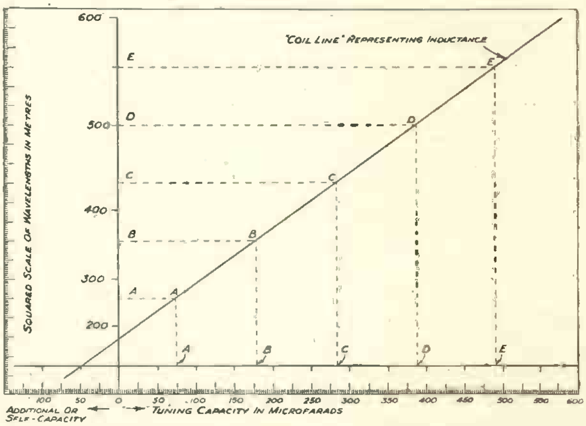


Fig. 6.—Graph showing the Relationship between Wavelength, Capacity and a Given Inductance.

The sloping line in this graph indicates a certain coil, and where this sloping line cuts the left-hand scale it does so at a point which gives us the value of the additional self-capacity of the coil and the wiring.

A, B, C, D and E are points along this line corresponding to wavelengths A′, B′, C′, D′ and E′, obtained by tuning capacity values A″, B″, C″, D″ and E″. It is obvious that, if we find another coil which has the same values—A′A″, B′B″, C′C″, D′D″ and E′E″—for wavelength and capacity, it must have the same coil line as the previous coil, and incidentally the same self-capacity.

Calibrated Instruments are Not Necessary

Now, even if our condenser is not calibrated, we must obviously arrive at the same value if we move the dial and then bring it back to the same setting it previously occupied. This would equally apply to an oscillator. Then, providing our wavemeter or oscillator will cover the wavelength range of our coil with its ·0005 mfd. variable condenser, and does not vary, we can check coils even though we may have no calibrated instruments. We shall, however, require an instrument which will show us when our coil and condenser circuit is in tune, and at the same time give a rough indication of the voltage developed across it. The most suitable instrument for this purpose is the valve voltmeter. Fig. 7 shows the circuit diagram of such an instrument.

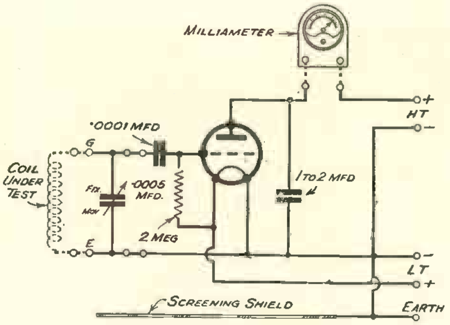


Fig. 7.—Circuit Connections for Valve Voltmeter.

Arrangement and Adjustment of the Apparatus

First we must set up and adjust the wavemeter. The variable condenser, together with the valve voltmeter and accessories, should be placed on a board and the final positions marked so that, should anything be disturbed, it can be set in place again. The earthing shield, or chassis, of the variable condenser, together with its moving vanes and the "common negative" of the valve voltmeter, should be "earthed," to avoid stray capacity effects, and a stand or mount provided for the coils, so that each coil may occupy exactly the same position as the previous one used.

Position of Coils is of Great Importance

It is of the greatest importance that this rule should be strictly adhered to, as laxity in this respect will introduce a multitude of erroneous readings due to too little or too much coupling between wavemeter and coil.

It may be necessary to check the coils again after they have been placed in their screening pots, but, as a rule, if due care has been exercised in the course of "potting" the coils to ensure that the positions occupied in the pots are identical, this refinement may be neglected.

Should it become necessary to do this a small fixed coil of one or two turns may be connected in series with the coil in its pot and used as a coupling coil to couple the screened coil to the wavemeter. Allowance will, of course, have to be made for the effect of this small coil upon the results, but the variations will be but small (Fig. 8).

Connecting up the Coils for Test

A coil is placed upon its stand and the end wires are taken straight to the test terminals. The top of the coil preferably to the one marked G and the bottom to the one marked E (see Fig. 7).

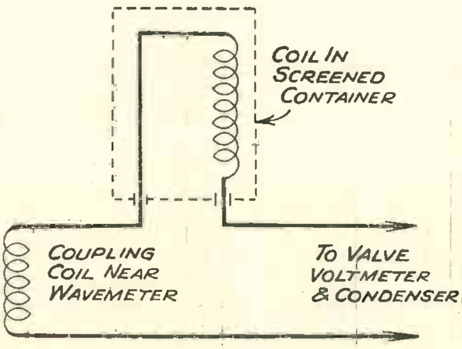


Fig. 8.—Method of Coupling Screened Coils to Wavemeter.

Two ways are available for testing—one where four or five readings are taken with one coil and the other where at each reading the total number of coils are tested. It is advisable to employ both ways—one as a check upon the other.

Adjusting the Wavemeter for Position

Before proceeding further, it is advisable to adjust the wavemeter for position with regard to the valve voltmeter and coil. This is easily achieved by adopting the following procedure: set the variable condenser to approximately mid-position. Gradually bring the wavemeter towards the coil whilst slowly rotating its tuning condenser, and at the same time observing the milliammeter needle, which will, when the wavemeter is fairly closely coupled and in tune with the coil and condenser, give a movement back towards zero. Now carefully adjust the wavemeter condenser until the maximum movement towards zero is obtained, keeping the wavemeter stationary. The milliammeter needle will now indicate a lower reading than when the wavemeter was out of tune. A suitable reading is about half-scale—if it reads less, bring the wavemeter closer—if more, move the wavemeter further away.

Repeat this performance, keeping the wavemeter in the position it now occupies, but with the variable condenser at (1) maximum, (2) at zero. One of two things may now occur—either you will obtain hardly any reading at maximum, or too much at zero.

The remedy is first to turn the wavemeter round, if necessary bringing it closer or moving it further away, until a milliammeter reading of not less than a quarter scale at zero and not more than three-quarter scale at maximum, is obtained. After this do not alter the relative positions of wavemeter to coil and condenser, etc., on any account.

It will be noticed that the milliammeter, when used with the valve voltmeter, works apparently the wrong way. When no H.F. voltage is present the reading is high, and the greater the amount of H.F. the lower the reading. This is due to the fact that leaky-grid detection is used.

Checking the Coils

Find, by experiment, the wavemeter readings corresponding (*a*) for five degrees on the variable condenser dial, and (*e*) five degrees lower than maximum on the variable condenser dial, using one of the coils which are to be tested. Choose any three intermediate readings corresponding to between (*a*) and (*e*) on the wavemeter as being suitable points to test at. Check (*a*) and (*e*) to ensure that the coil will cover the required waveband.

Construct two tables as shown, and mark down carefully the readings obtained on the milliammeter and variable condenser for each coil against the appropriate wavemeter settings *a*, *b*, *c*, *d*, *e*. Do this with Table 1 and repeat with Table 2. This will provide a check on your own skill and guard against errors.

Do not vary the values whilst testing is in progress.

TABLE I

Wavemeter Dial Setting.	Milliammeter Reading.	Tuning Condenser Setting.	Number of Coil.

TABLE II

Number of Coil.	Milliammeter Reading.	Tuning Condenser Setting.	Wavemeter Setting.

Precautions to be Taken

When changing coils for the purpose of taking readings, be extremely careful to replace each in exactly the same way in the same position as the previous one, and

This article on "Ganged Coil Circuits" is continued in Part 7. Ready October 28th. Order your copy to-day.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SHORT WAVE FOUR

FAULT LOCATION IN HOME CONSTRUCTED SETS

RECENT DEVELOPMENTS IN AMATEUR TRANSMISSION AND RECEPTION

SERVICING EDISON BELL RECEIVERS

1/-

Part 7

IN ABOUT 24 WEEKLY PARTS

exercise the greatest care not to displace any part from its previous position, otherwise errors may occur.

Effect of Hand Capacity

Care, too, should be taken not to bring the body into too close proximity to the wavemeter coils, nor to the coils undergoing test. A simple and instructive experiment will serve to emphasise this point. With the wavemeter set at one of the five points, vary the variable condenser until the milliammeter shows its maximum variation. Then extend a hand towards the coil under test and observe how the milliammeter reading varies with the proximity of the hand. A loss is almost always the invariable result, as even the careful retuning of the variable condenser will not always bring the variation of the milliammeter back to its previous value. Aged and decrepit high tension batteries, semi-used accumulators and mains units should not be used either for the wavemeter or the valve voltmeter as, should they be used, the voltages are likely to vary whilst testing is in progress, with consequent and apparently mystical errors.

Making Use of the Tables of Results

Looking again at Fig. 6, it will be obvious that coils having the same variable condenser reading and milliammeter reading for the same wavelength setting, by the wavemeter, are, for all practical purposes, identical, and can therefore be used right away in ganged circuits without further attention. It remains to consider those which do not correspond.

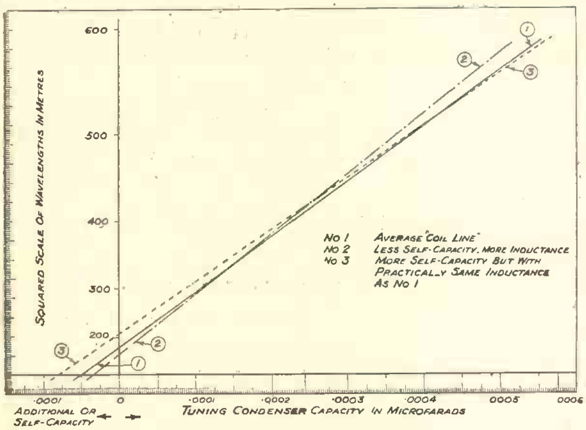


Fig. 9.—GRAPH SHOWING VARIATIONS IN SLOPE OF "COIL LINES" DUE TO VARIOUS FACTORS.

Three Things which May Vary in a Coil

Now there are three things which may vary in a coil. (1) Its self-capacity; (2) its inductance, and (3) its resistance at high frequencies. The effect of resistance will be the same as if there was a loss due to a load across the coil and condenser, and the backward reading of the milliammeter will be less in the case of a coil having a greater resistance. This can be seen by inspection of the table of results. Choose as a standard one of the coils which will tune the waveband required.

Causes of Faults in Coils

Should the milliammeter reading prove to be the only factor which varies, the variation is probably due to a difference of coil resistance, provided, of course, that the conditions under which the tests were carried out were identical. The best coils will be those which give the greatest milliammeter deflection whilst giving the same capacity and inductance values.

Now the inductance, and with it the self capacity of the coils, will vary with the spacing of the turns, and those which do not correspond to the "good" ones should be checked for total turns and spacing of turns.

If the variable capacity values are progressively less than that of the standard "good" coils at the lower values of the wavelength band (corresponding to lower values of the wavemeter condenser scale), but show a fairly good corresponding value at the higher wavelengths, the variations are in all probability due to self-capacity.

Should the variable capacity values progressively decrease at the higher values, the inductance value is at fault. Fig. 9 shows these points graphically.

If the variations are very large there is either something radically wrong with the coil or an error in the testing of it. Check everything over again very carefully. On the other hand, if the variations are slight it may be possible by means of a little judicious juggling to match it with the "good" ones. It is assumed that it has the same turns as the other coils.

How to Adjust the Coil

First examine it very carefully and see if there appears to be any variation in the wire covering, if it is wound more closely or loosely than the others.

Use the back of the thumb-nail to press against the wire, taking care not to damage the covering, and slowly rotating the coil in the hand whilst doing so. As a rule, very little adjustment indeed is needed and, after having carefully moved the turns in this manner, test the coil again.

Spacing the turns apart, as a rule, will decrease the inductance value, and with it the self-capacity, whilst the reverse action occurs when the turns are squeezed together.

After a little practice, one will soon acquire the knack of adjusting the spacing, and with the acquisition of this, matching will become more easily accomplished.

Testing Coils of Various Sizes for Matching

As before, we will require to choose one coil to which the others are to be matched. If we have a wavemeter the wavelength band of the coil can be easily checked. Should only an uncalibrated oscillator be available, the waveband can be checked by either of two methods. One is first to check the oscillator with a receiver against one or two stations of known wavelength by the process of heterodyning them and listening to the beat note in the receiver—zero between the "chirps" will indicate resonance, the note rising on either side of this zero setting when a station is heterodyned.

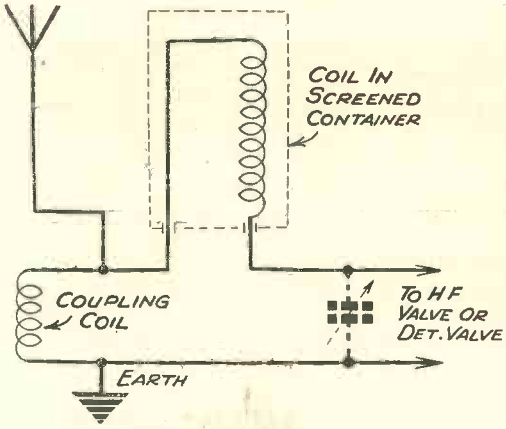


Fig. 10.—Method of Checking Coil for Waverange from Aerial.

The other method consists in winding a coil of two or three turns, connecting it in series with the coil under test, the condenser across the two in series and coupled to a detector valve or H.F. valve of a receiver (Fig. 10), and the aerial and earth connected across the coil of the few turns. The settings of the condenser which tunes the combination are observed for various stations and a coil chosen accordingly which will tune in to those required.

Check Coils in their Containers

It will be advisable to check coils of various sizes in the actual containers or screening pots in which they are to be used, and in order to obtain a coupling with the wavemeter or oscillator, a coil of a few turns will have to be used, with each coil tested, otherwise discrepancies will occur.

The procedure to be adopted is practically the same as already described. One point of note is that, generally speaking, great reliance cannot be placed on the milliammeter readings as a sign of coil goodness, as the coils are all varied. The coupling coil only is coupled to the wavemeter, and it is advisable to place the other coils in their pots at approximately the same distance away from the coupling coil each time, in order to avoid effects on it and the

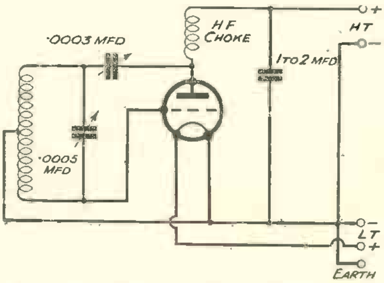


Fig. 11.—Circuit Connections of an Oscillator (Hartley Type.)

wavemeter from the proximity of the metal container.

Readings are taken as before, and it will doubtless occur with certain coils that less tuning condenser will be required for the higher values of the waveband, whereas at the lower values the tuning condenser variations are little different from the standard.

In this case it is probably due to the coil having too great an inductance, and it may happen that after adjustment by altering the spacing of the turns has been tried that they will still not match. In this case it will be necessary to remove turns.

Do not Remove Too Many Turns

Remove one at a time, then test and then try the effect of varying the spacing, and test again before removing further turns. Should too many turns be removed, there is no need to scrap the coils, as the loss of a single turn will make little difference in practice—use this coil now as the standard to which to test the others. In all cases test with the coils in their containers. Coils which require more capacity at the higher settings of the waveband have too little inductance, and will have to be rewound.

At this juncture it will be as well to state that coils of varying sizes, even when in shielded containers, and even when matched for inductance, will not of necessity possess the same high frequency resistance values, and consequently the merit or goodness of these will vary accordingly.

A FEW PRACTICAL HINTS

When constructing coils for test, remember our old enemy—the perspiration from the body—and hold the wire whilst winding with a piece of dry chamois leather or dry felt, taking care to avoid abrasion of the wire covering.

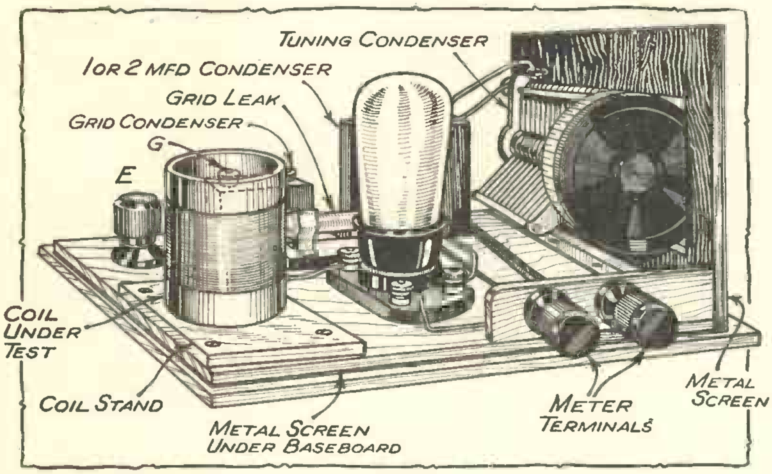


Fig. 12.—SUITABLE LAY-OUT OF VALVE VOLTMETER AND TUNING CONDENSERS.

What to Do if Moisture is Suspected

Should moisture be suspected in the wire covering, carefully bake the whole batch of coils and re-test before attempting to adjust any. When baking it is preferable to use a gentle heat for a longer time than a stronger heat for a shorter period. Coil formers are apt to shrink and to perform other weird contortions under sudden heat.

The main secret of success lies in the careful attention to details, and if due care is taken in the construction of the coils the testing will be less difficult.

The reader who carefully carries out the testing and matching of the coils and as carefully fits them in their screening containers, taking care to ensure that the positions of each with respect to its surroundings—sides and ends of containers—is the same, will not only possibly save himself the trouble of testing them in the containers, but have the satisfaction of having a really well-ganged receiver—at least as far as the coils are concerned.

If hand capacity effects are troublesome, fit a metal shield and earth it.

While testing do not alter the H.T. or L.T. values—use the same values for all tests.

Fig. 13.—CONNECTING BOTTOM LEAD OF COIL TO TERMINAL E.

This is done after the coil has been placed upon its stand. The end wires are taken straight to the test terminals, the top of the coil preferably to the one marked G, and the bottom to the one marked E.

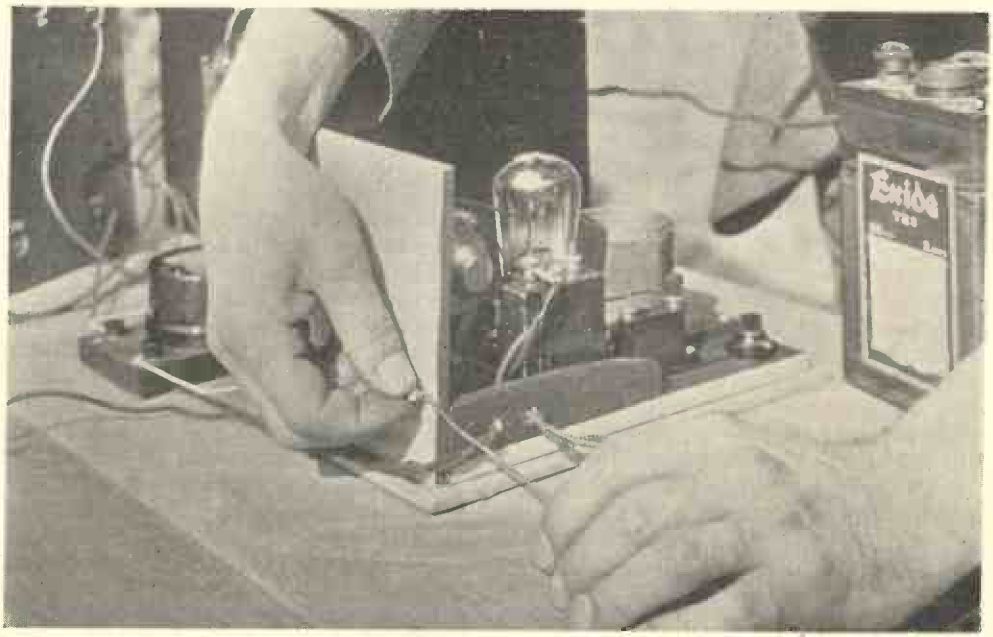


Fig. 14.—CONNECTING EARTHING WIRE TO SCREEN.

The screening shield is earthed in order to avoid stray capacity effects.

Constructing a Simple Valve Voltmeter

This useful piece of apparatus can be very easily constructed in a little time, and will be found to be extremely useful for a variety of purposes, particularly when it has once been calibrated.

As it is not necessary for the purpose of this article that it be calibrated, it is not proposed to go into this question at present.

Materials Required

Suitable baseboard.
1 Valve holder (*Benjamin*).
1 Valve (2 volt), (Mazda H.210).
1 ·0001 mfd. mica condenser (*T.C.C.*).
1 2-meg. leak (*Ediswan*).
1 1-mfd. or 2 mfd. condenser (*T.C.C.*).

2 H.T. 2 L.T. 1 Earth 1 G. 1 E.	Insulated terminals.	Alternatively	2 meter terminals, one earth terminal and leads for + − HT and + − L.T.

A coil of Glazite and some aluminium foil or tin foil.
A milliammeter, preferably one or two ma. full scale, but a 5 ma. full-scale instrument may be used if desired. Suitable moving coil meters are manufactured by Ferranti, Weston, etc.

Baseboard

For the purpose of coil testing, it is advisable to use a larger baseboard than would normally be required, in order to accommodate the variable tuning condenser, and possibly the stand for the coil.

A glance at the circuit of the voltmeter (Fig. 7) will show how simple it is to construct, and it is not proposed to give constructional details here, but rather a few useful practical hints on its construction.

Keep the ·0001 mfd. grid condenser and leak close to the valve holder, and do not use longer wires than necessary. The by-pass 1 or 2 mfd. condenser should also be kept fairly close to the valve holder. Fix to the underside of the baseboard a strip of foil to act as a screen. This should extend as far as the valve holder, but preferably not under the coil stand. A screen should also be placed so that the variable condenser is shielded from the hand. Both these screens should be connected to −L.T. and earthed.

It is not essential to use only the materials specified here, but if these are used, satisfaction will be obtained.

When setting up the meter for test start first with a very low value of H.T. and gradually increase it until the milliammeter reads nearly full scale. Sudden application of full H.T. may pass a current which might damage the meter.

Fig. 12 shows a suitable layout for valve, voltmeter, coil stand and tuning condenser. Any good condenser may be used.

The Oscillator (Fig. 11)

This has a circuit which is simplicity in itself. In order to give a decent output it is advisable to use a valve of the L.F. class.

A metal screen should be placed under the baseboard connected to −L.T. and earthed. This will tend to maintain stability. The ·0003 mfd. variable condenser may be of the pre-set type, and when once adjusted can be left in position and, if possible, preferably locked. It is first set to zero and then gradually increased till oscillation starts, then increased slightly more and set.

The oscillator may be checked against a wavemeter and calibrated, or against received stations by the heterodyne method.

Centre-tapped coils such as McMichael "Dimic" and Lewcos are very suitable for this purpose.

When calibrating the oscillator, check the settings of the ·0003 mfd. condenser and make a note of the valve and voltages used.

In subsequent cases use the same valve with the same H.T. and L.T. values, otherwise there is a likelihood of the wavelength altering.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION I—OHM'S LAW

OHM'S LAW sounds very imposing, but it is really quite a simple matter. Ohm found that the voltage across the ends of a wire carrying an electric current was always PROPORTIONAL to the current in the wire. What do we mean by "proportional"? Well, let us consider an actual example such as Ohm might have encountered during his experiments.

A Simple Experiment

Suppose that we take a length of wire, a battery, a voltmeter, and an ammeter, and connect them together as shown in Fig. 1. B is the battery, the zig-zag line XY represents the wire, V is the voltmeter, and A is the ammeter. Suppose that when the voltage reading of V is 10 volts, the reading of A is 2 amps. What will happen if we increase the voltage of the battery so that V's reading is twice 10 volts (= 20 volts)? Ohm found that when the voltage reading was doubled, the current reading was also doubled, and that when the voltage reading was multiplied by five, the current reading was also multiplied by five.

In fact, he found that by whatever number the voltage reading was multiplied or divided, the current reading was multiplied or divided by that same number, always provided that he used the same length of wire during the course of each experiment.

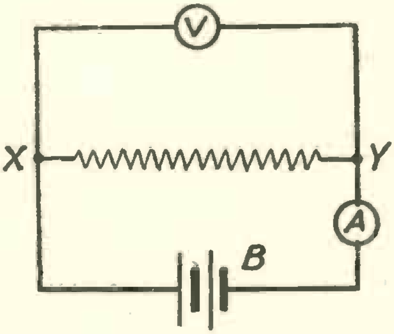


Fig. 1.—A SIMPLE EXPERIMENT TO ILLUSTRATE OHM'S LAW.

B, is a battery; XY, a length of wire, V, a voltmeter, and A, an ammeter.

Replacing Words with Letters

Now mathematics is really a shorthand notation; that is to say, it provides a quick way of expressing facts. When we state that "the voltage is proportional to the current," we are stating in a shorthand way the abiding results of a certain group of Ohm's experiments. But we can say this more briefly by replacing the words with letters. We use E for volts indicated by the voltmeter and I for amperes indicated by the ammeter. Then we shall have :—

E (volts) equals I (amps.) × R (a constant number, and which is actually equal to the resistance, in ohms, of the length of wire XY in Fig. 1),

i.e., $E = I \times R$
or, Volts = Amps. × Ohms.

An Equation

The piece of mathematical shorthand $E = I \times R$ is called an EQUATION, because it states that one thing, on the left-hand side of the = sign, is equal to some other thing on the right-hand side. We often have to deal with more than one equation in mathematical work, and so we number each equation (1), (2), (3), etc., for easy reference. You will have gathered already that the mathematician is really a lazy man who likes to find the shortest way of doing things. The equation which we have just set down will obviously be number (1), so ;—

$$E = I \times R \quad . \quad . \quad . \quad (1)$$

We seldom use even the multiplying sign in mathematics, and instead of writing $I \times R$ we should write simply $I\,R$, so that we at last come to the shortest way the mathematician has of writing this equation which expresses Ohm's discovery, viz. :—

$$E = I\,R \quad . \quad . \quad . \quad (1)$$

Expressing this in words we have :—

"The voltage across the ends of a wire carrying an electric current is equal to the current in the wire multiplied by the resistance of the wire."

How the Formula is Used

Sometimes we refer to equation (1) as a FORMULA, and we use this word because we are thinking of the equation in a different sense from that previously. The equation is the mathematical statement of a relation, or connection, between the three factors represented by E, I, and R. If we know the value of two of these factors, we can predict the value of the third factor corresponding to the values of the first two.

Example 1.—Thus, consider the case of a valve which requires a filament voltage of 4 volts and takes a filament current of ·25 amps. We are told the values of E and I, can we find the value of R? Well, we have our formula :—

$$E \text{ (volts)} = I \text{ (amps.)} \times R \text{ (ohms)}.$$

Let us write the actual values in place of the mathematical shorthand ; we have :—

$$4 = \cdot 25 \times R \text{ (ohms)},$$

i.e., that ·25 of R (ohms) equals 4; what is R?

It is a simple step in arithmetic to see that

$$R \text{ (ohms)} = \frac{4}{\cdot 25} = 16$$

so that the filament resistance is 16 ohms.

Example 2.—What is the voltage across the ends of a resistance of 3,500 ohms which is carrying a current of 15 milliamps. ?

Now, as before,

$$E \text{ (volts)} = I \text{ (amps.)} \times R \text{ (ohms)}$$

and we must substitute the actual values for I and R, but we are given I in milliamps., and in our formula I is in amps. ; thus we must convert the 15 milliamps. into amps., which we can do if we remember that 1,000 milliamps. = 1 amp. Therefore 15 milliamps. = $\left(\frac{1}{1{,}000} \times 15\right)$ amps. Substituting the values in the formula, we have :—

$$E \text{ (volts)} = \left(\frac{1}{1{,}000} \times 15\right) \times 3{,}500$$

and when we remove the brackets and work out the arithmetic we find the answer to be :—

$$E \text{ (volts)} = 52 \cdot 5.$$

Similarly we could find the current flowing through a resistance when we know the value of the resistance and the voltage across its ends.

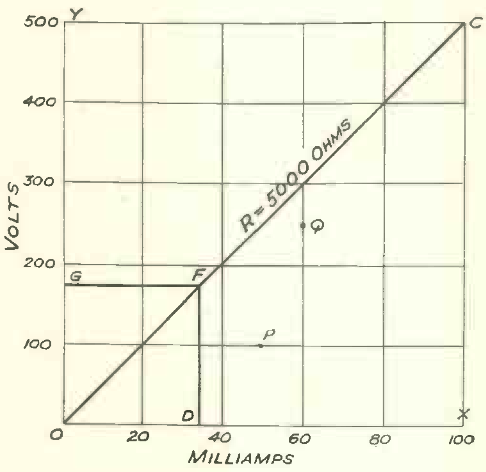


Fig. 2.—A SIMPLE GRAPH.

Marks are made along two of the ruled lines OX and OY. The marks along OX correspond to the values of current, and those along OY to value of voltages. Thus every vertical line corresponds to some particular value of current, and every horizontal line to a particular value of voltage.

Charts and Graphs

An equation, or formula, is very useful for solving problems, but the engineer and the experimenter cannot always spare the time necessary for working out their problems in this way. They prefer to use CHARTS and DIAGRAMS (GRAPHS) in which all their problems are already worked out, so that they need only refer to the appropriate answer. Let us suppose that we are going to use a resistance of, say, 5,000 ohms in a circuit in which the current can be varied between 0 and 100 milliamps., and we want to know the voltage across the ends of the resistance for each value of current. Equation (1) tells us that the voltage is proportional to the current, so that if we work out the voltage for one particular value of current we can make a table showing the voltage at any current value. We may choose any convenient current value for our calculation, and 10 milliamps. is an easy value to work with. We have :—

$$E \text{ (volts)} = I \text{ (amps.)} \times R \text{ (ohms)}$$

and 10 mA. $= \frac{10}{1,000}$ amps.

then E (volts) $= \frac{10}{1,000} \times 5,000$

i.e., E (volts) $= 50$.

Now the voltage is directly proportional to the current, so that at 1 milliamp. $\left(= \frac{10}{10}\right)$ the voltage will be $\frac{50}{10}$ volts = 5 volts. Similarly at 50 milliamps. ($=10 \times 5$) it will be 50×5 volts = 250 volts, and our table will be like this :—

Current (milliamps).	Voltage (volts).
1	5
2	10
3	15
4	20
5	25
6	30
7	35
8	40
9	45
10	50
20	100
30	150
40	200
50	250
60	300
70	350
80	400
90	450
100	500

Limitations of the Table

We should have to make a new table for each value of resistance we are using, and, moreover, the table is not really complete because it does not give the voltages corresponding to the intermediate fractional values of current, such as, for instance, $5\frac{1}{2}$ and $21\frac{3}{4}$ milliamps. We could calculate these intermediate values and include them in the table, but it would not be long before the table became very cumbersome.

How Intermediate Values could be Calculated

We could, of course, find our intermediate values in this way: suppose we wish to find the voltage value corresponding to $5\frac{1}{2}$ milliamps. From the table we see that 5 milliamps. produce a voltage across of the resistance of 25 volts, and 6 milliamps. produce 30 volts. Therefore a current of $5\frac{1}{2}$ milliamps., which is halfway between 5 and 6 milliamps., corresponds to $27\frac{1}{2}$ volts, which is half-way between 25 and 30 volts.

In this particular instance this process of calculation (which the mathematician calls INTERPOLATION) produces the correct answer, but in the majority of cases, where we have to deal with tables drawn up from more complicated formulæ, this method will not give a strictly accurate answer, although it generally gives an answer which is *nearly correct*, and which the mathematician calls an APPROXIMATION.

This additional calculation also takes a certain amount of time, however, and there is another easy way of representing these corresponding values of current and voltage, and that is by means of a diagram or graph.

How a Graph is Prepared

The graph is drawn on "squared paper" —*i.e.*, paper on which lines are ruled in two directions so as to produce a pattern of squares Fig. 2 shows such a diagram.

For the benefit of those who are unfamiliar with the process of plotting a graph, detailed instructions are given in the following pages, together with a series of diagrams showing every step in the construction. Once the details have been grasped the reader will find it an easy matter to construct graphs for any two quantities which vary with respect to each other.

HOW TO MAKE A GRAPH

Whenever you buy a valve you will find inside the carton a graph showing the

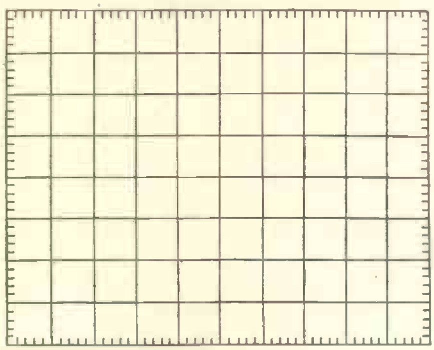


Fig. 3.—MAKING A SIMPLE GRAPH.

We are going to plot a graph showing the relation between resistance and length of a No. 30 SWG Copper Wire. First obtain a sheet of squared paper of a convenient size. The best type of paper to use has every fifth or tenth line emphasised with the smaller squares shown faintly. In the above illustration the smaller squares have been omitted.

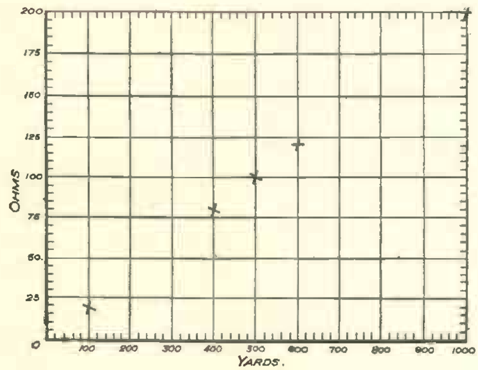


Fig. 5.—MAKING A SIMPLE GRAPH.

Now plot on the graph a few points which have been obtained from the table. The points plotted above are the following :—200 ohms, 1,000 yards ; 120 ohms, 600 yards ; 100 ohms, 500 yards ; 80 ohms, 400 yards ; 20 ohms, 100 yards.

characteristics of the valve. The following notes show how these graphs are constructed.

An Actual Case

You will see from another section of this work, if you do not already know it, that the resistance of a length of wire is proportional to its length. For example :

If 1,000 yards of No. 30 S.W.G. copper wire has a resistance of 200 ohms ; 500

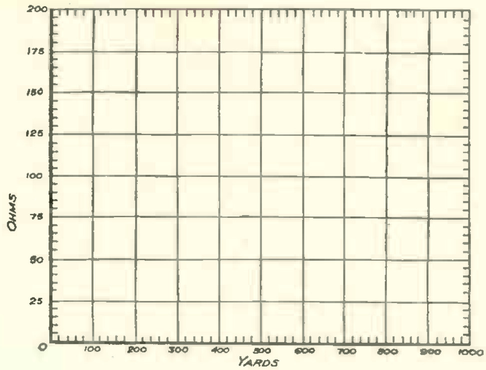


Fig. 4.—MAKING A SIMPLE GRAPH.

The next point is to obtain from a table a number of corresponding values of resistance and length for this type of wire. Next mark the horizontal and vertical scale on the graph paper to agree with the maximum values of resistance and length. In the present case the highest values are 200 ohms and 1,000 yards respectively.

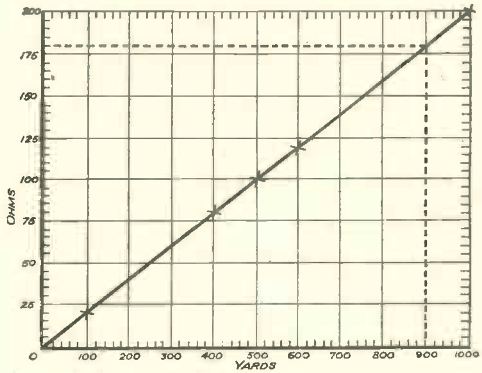


Fig. 6.—MAKING A SIMPLE GRAPH.

Now join the plotted points by means of a smooth line or curve. In the present case all the points can be joined by a straight line. The chart is now completed and can be used for reading off any intermediate values desired. For instance, it can be seen that 900 yards have a resistance of 180 ohms.

yards have a resistance of 100 ohms ; 100 yards have a resistance of 20 ohms, etc.

Now take a sheet of squared paper.

Mark on it two scales, one for resistance and one for length. Arrange each scale as far as possible so that it will occupy all the space available. For example, in the present instance the scale of length should be from 0 to 1,000 yards and the scale of resistance from 0 to 200 ohms.

The chief art in drawing a graph is to fix the scales so as to make the best use of the space available. The next stage is to mark on the graph paper points corresponding to the values of resistance and length. This stage is shown in Fig. 5.

Now join the dots by a smooth line or curve. The graph so formed is shown in the next illustration, and from it you can read off the resistance corresponding to any length of the wire from 0 to 1,000 yards. This is, of course, a very simple example, but even in this case it can be seen that this graph takes the place of a table containing hundreds of entries. Now try another case, Wavelengths in Metres and Frequency in Kilocycles.

Prepare the chart as before, making the scales to suit the values which have to be charted. Next plot the points corresponding to a few selected values. This has been done in Fig. 8.

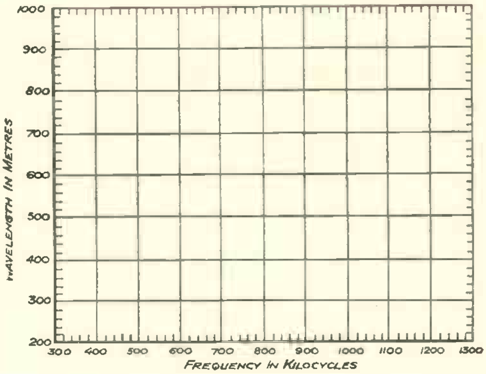


Fig. 7.—Wavelength and Frequency Chart.

Here again the scales must first be decided upon to suit the limits of the two variables which are to be plotted.

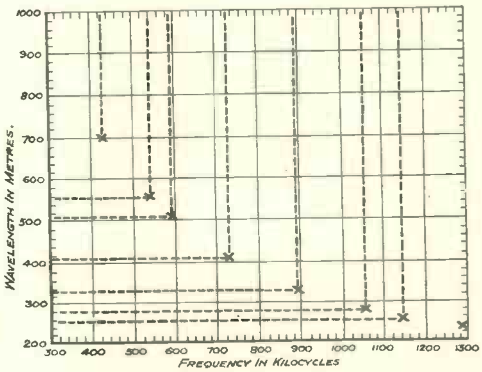


Fig. 8.—Wavelength and Frequency Chart.

After the scales have been fixed a number of points taken from a wavelength-frequency table are plotted as shown above.

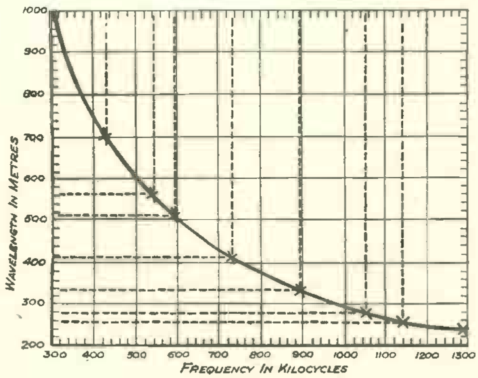


Fig. 9.—Wavelength and Frequency Chart. Completed.

Joining Up the Points

In this case the points do not lie on a straight line so that a smooth curve must be drawn to take in all the points. This curve enables you to read off the wavelength corresponding to any given frequency or the frequency corresponding to any given wavelength between the limits of the chart.

General Remarks on Graphs

There are two great advantages in the use of graphs as compared to tables. First, a graph shows at a glance how one quantity alters when another quantity is varied. (2) A graph enables corresponding values of two variable quantities to be read off at a glance. For instance, the valve characteristic curves found in every valve carton show at a glance how the plate current varies according to the grid voltage so that the set designer can readily select the most suitable grid bias to use to obtain the results required.

In many cases, such as the valve curves mentioned above, the charts are not prepared from tables, but are plotted as a result of actual experiments. Apparatus is fitted to enable the corresponding readings to be taken of the two variables. These are recorded and afterwards plotted in graph form.

The use of special types of squared paper, viz., logarithmic and double-logarithmic paper, will be explained fully in a later article.

Every vertical line in Fig. 2 corresponds to some particular value of current, and every horizontal line to a particular value of voltage.

An Example of a Useful Graph

For instance, the point P is on the vertical line representing 50 milliamps., and on the horizontal line representing 100 volts. Similarly Q corresponds to values of 60 milliamps. and 250 volts. The intersection of each pair of vertical and horizontal lines corresponds to one value of current and to one value of voltage. The line OC passes through all the points corresponding to the values in the table and thus it represents our 5,000 ohms resistance, and it enables us to find the voltage across the ends of the resistance at any current value shown along the line OX, and *vice versâ*. Let us check this. From the table the voltage produced by a current of 35 milliamps. is 175 volts. On the graph DF is the line representing 35 milliamps., and it meets OC at F. The horizontal line GF through F corresponds to 175 volts. The reader will be able to check other pairs of values for himself.

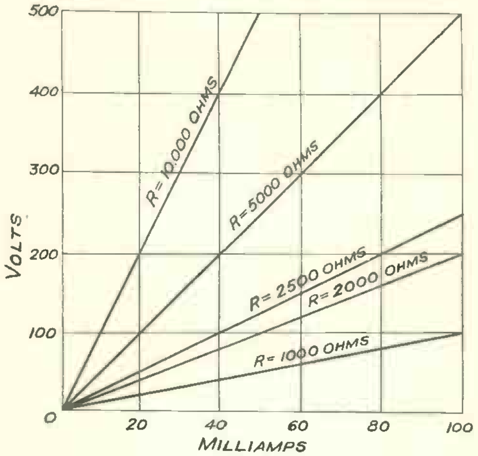


Fig. 10.—This shows a Chart Drawn for Resistance Values of 1,000, 2,000, 2,500, 5,000 and 10,000 Ohms.

Showing Values of Current for Different Values of Resistance

In addition to the fact that this graph is much more compact than the table, and that it gives every intermediate value of current, it possesses another advantage. Other lines, corresponding to different values of resistance, can be drawn on the one graph, and Fig. 10 shows such a chart drawn for resistance values of 1,000, 2,000, 2,500, 5,000, and 10,000 ohms. Each line was found by calculating some of the current and voltage values, as previously, for each resistance, and the points were joined to form the lines.

Whatever value of resistance we use, we shall always find that this graph is a straight line. It is the graph which represents our equation (1) when R is fixed at a particular value. E and I are both variable, and we have one variable in the numerator on each side of the equation. Such an equation always forms a graph which is a straight line.

QUESTIONS AND ANSWERS

What determines the Strength of an Electric Current flowing through a Wire?

(*a*) The electrical pressure between the ends of the wire.

(*b*) The resistance of the wire.

Thus a high voltage applied across the ends of a wire having a low resistance would give rise to a very heavy current. Conversely a low voltage applied across a wire of high resistance would produce only a very small current in the wire.

What is Ohm's Law?

Ohm's Law summarises the information contained in the answer to the previous question.

Stated briefly it is:

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}}$$

Why is Ohm's Law so useful in Electrical and Wireless Engineering?

Because by its use, if any two of the three quantities involved in an electric circuit, namely, voltage, current or resistance, are known, this law enables the other one to be readily calculated. Thus:

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}}$$

$$\text{Voltage} = \text{current} \times \text{resistance.}$$

$$\text{Resistance} = \frac{\text{voltage}}{\text{current}}.$$

Why are Letters such as X, Y, A and B used so frequently in Mathematical Calculations?

Simply as a kind of shorthand. For instance, X is often used to represent an unknown quantity merely for the purpose of avoiding the labour of writing down "unknown quantity" every time it has to be referred to.

What is an Equation?

A statement that one set of quantities is equal to another quantity or set of quantities.

For example, yearly rainfall in the Manchester area = January rainfall + February rainfall + March rainfall . . . + December rainfall, is an equation, and by its use, if all the quantities were known except one, the unknown quantity could be easily calculated.

Another example is,

Distance travelled = speed × time of travel.

Here again if any two quantities are known the third can be calculated.

To save time the mathematician indicates the various quantities by different letters. Thus he might write the last example as,

$$s = v \times t.$$

What are the Three Ways of indicating the Relation existing between Two Variable Quantities?

(*a*) By an equation or formulæ.

(*b*) By a table giving corresponding values of the two variables.

(*c*) By a graph or chart.

What are Some of the Advantages of a Graph as compared with a Table of Values?

(*a*) The shape of the graph shows at a glance the manner in which one quantity varies with respect to the other. Thus if one of the quantities remains constant while the other varies, the graph would consist of a straight line parallel to one scale of the graph.

If both quantities increased at the same rate the graph would take the form of a line at 45 degrees to each scale.

If the two quantities were related in an equation such as $X^2 + Y^2 = 16$, the graph would take the form of a circle 4 inches in radius having its centre where the X and Y scales meet.

What is the Most Important Point to observe in drawing a Graph?

To select the scale graduations so as to suit the limits of the two variables. In this way one is able to make the most use of the space available and thus keep the scale graduations as open as possible.

SHORT WAVE FOUR VALVE SET

FOR RECEPTION FROM 15 TO 100 METRES

By EDWARD W. HOBBS, A.I.N.A.

THIS 4-valve receiver, specially designed for reception of the short-wave transmissions on 15 to 100 metres, will, under favourable circumstances, give loud speaker reception of all the main American and Continental stations.

Fig. 1.—The Completed Receiver Ready for Operation.

The Circuit

The circuit shown in Fig. 2 is remarkably simple and straightforward ; it comprises a screened-grid H.F. valve, transformer coupled to the leaky grid detector. The secondary coil of the transformer is tuned by a variable condenser, while reaction is controlled on the Reinartz system by a small variable condenser. A resistance capacity coupling stage and a transformer-coupled L.F. stage complete the main features of the circuit.

Single knob Tuning

Simplicity of control is attained by the use of an untuned aerial circuit consisting of a high frequency S.W. choke between the grid of the S.G. valve and earth. The high amplification factor of the S.G. valve increases the efficiency of the set, and in conjunction with the aperiodic aerial circuit ensures smooth reaction control and the absence of unpleasant hand capacity effects.

The tuned high frequency transformer coupling is quite efficient and ensures good selectivity, as there is only very light damping on the detector valve grid circuit.

The detector valve is coupled to the first L.F. valve by a specially arranged resistance capacity coupling which takes full advantage of the amplification factor of the detector valve.

Power or Pentode Valve

The first L.F. valve is transformer coupled to the second L.F. valve, which may either be a small power valve or a pentode, the latter being used when the set is chiefly intended for loud speaker

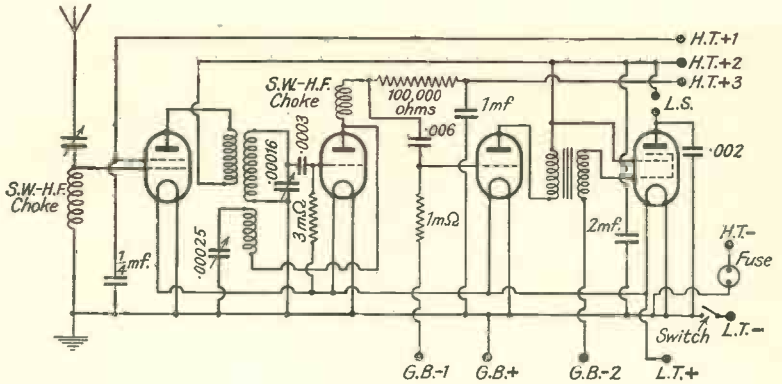


Fig. 2.—Theoretical Circuit Diagram.

The circuit comprises a stage of H.F. amplification followed by a leaky grid detector, a stage of R.C. amplification and a transformer coupled L.F. amplification stage. A pentode valve is used for loud speaker reception.

work. The only difference in the circuit is the provision of a H.T. plus lead to the auxiliary grid of the pentode ; but this lead should be omitted when a small power valve is used.

In practice, a standard 5-pin valve holder is wired up for the pentode, consequently, when an ordinary power valve is used the centre pin lead becomes inoperative.

When a pentode valve with side terminal is used, the H.T. plus lead should be a short length of flexible wire connected at one end to the H.T. plus side of the circuit.

Although specially intended for short-wave work this receiver can be used for reception of the medium or long wave broadcast bands by substituting plug-in coils of suitable values. Selectivity on these wavelengths is not very good, although reception is of high quality.

Arrangement of the Receiver

The set as a whole is arranged compactly in a simple, straightforward case which incorporates a compartment for the high and low tension batteries and the grid bias battery. Either an external loud speaker or headphones can be used as desired, by connecting them to the loud speaker terminals on the right-hand end of the case. Aerial and earth terminals are provided at the opposite end.

Components for the Receiver

The following components are required for this receiver :—

Coils.

2 sets plug-in coils, 15 to 100 metres. *Clarke's "Atlas."*

Coil Holders.

1 Low-loss plug-in coil holder. *" Wearite."*

1 Dual plug-in holder with vernier control. *" Kalmo."*

Variable Condensers.

1 ·00002 J.B. variable neutralising condenser. *Jackson Bros.*

1 ·00016 S.W. variable condenser. *" Eddystone."*

1 ·00025 S.W. reaction condenser with slow motion knob and dial. *" Polar."*

1 Slow motion dial and knob. *" Ormond."*

Fixed Condensers.

1 2 mfd. Condenser. *T.C.C.*
1 ¼ mfd. ,, *T.C.C.*
1 1 mfd. ,, *T.C.C.*

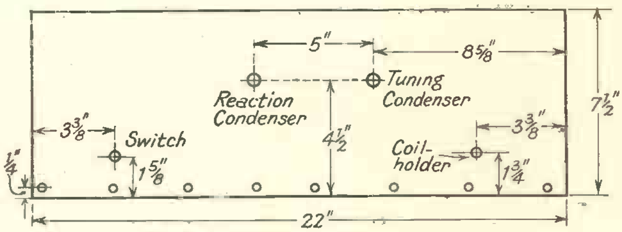


Fig. 3.—Components on the Panel.

Dimensioned sketch of the panel, as seen from the front, showing where to drill for the components and fixing screws.

1 ·006 mfd. condenser with G.L. clips. *T.C.C.*
1 ·002 mfd. condenser. *T.C.C.*
1 ·0003 mfd. condenser with G.L. clips. *T.C.C.*

VALVE HOLDERS.

3 4-pin valve holders. *Bulgin.*
1 5-pin valve holder. *Bulgin.*

TRANSFORMER.

1 L.F. Ferranti AF8.

SUNDRIES.

1 Fuse holder and 3 spare "scrufuses." *Belling-Lee.*
1 On-off switch Q.M. and B. *Bulgin.*
1 100,000 ohm spaghetti resistance. *Lewcos.*
1 S.W. H.F. choke. *Wearite.*
1 S.W. H.F. choke. *Bulgin.*
1 3-megohm grid leak. *Graham Farish.*
1 1 megohm grid leak. *Graham Farish.*
1 Battery cord 7-way. *Belling-Lee.*
3 Wander plugs. *Belling-Lee.*
2 Terminal mounts and terminals. *Belling-Lee.*
4 R type terminals with indications "aerial," "earth," "L.S.+," "L.S.−." *Belling-Lee.*
1 Coil yellow Glazite. *Lewcos.*
1 Coil red Glazite. *Lewcos.*
2 Lengths tinned copper wire and glazite sheathing. *Lewcos.*
2 Yards rubber covered flexible wire. *Lewcos.*

LOUD SPEAKER.

Permanent magnet moving coil type D9 (*Igranic*).

BATTERIES.

1 "Drydex" green triangle H.T. battery, 120 volts, No. H1012. *Exide.*
1 "Drydex" grid bias battery, 16½ volts, No. H1002. *Exide.*
1 "Gel-Cel" low tension 2-volt accumulator, No. JZ4. *Exide.*

VALVES.

1 P.M.12A metallised. *Mullard.*
1 H.L.210 metallised. *Mazda.*
1 P.M.I.H.L. *Mullard.*
1 P.M.22 or P.M.202. *Mullard.*

BASEBOARD.

Whitewood, 22 inches long by 8½ inches wide, ¾ inch thick.
Panel, 3-ply oak faced 22 inches long by 7½ inches wide, $\frac{3}{16}$ inch thick.
Brackets, 1 piece, pine 16 inches long, 1½ inches wide, ⅜ inch thick. *Sinclairs.*

Materials for the Case

The following comprises the needful materials for a compact case, but if preferred the set can be housed in a ready-made cabinet with a self-contained loud speaker.

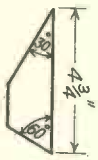


Fig. 4.—WOODEN PANEL BRACKETS.

Three brackets shaped as here shown are used to support the panel.

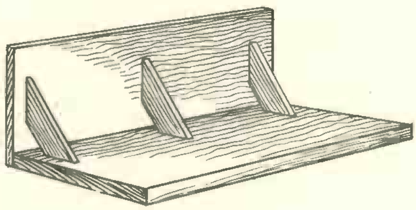


Fig. 5.—PANEL BRACKET IN POSITION.

The brackets are glued and screwed to the panel and baseboard to ensure absolute rigidity.

TOP.

1 piece 24 inches long by 10¾ inches wide, ⅜ inch thick.

ENDS.

2 pieces, 12 inches long by 10 inches wide, ½ inch thick.

FRONT.

1 piece 23 inches long by 12 inches wide, ⅜ inch thick.

BACK.

1 piece 23 inches long by 7 inches wide, ⅜ inch thick.
1 piece 23 inches long by 5 inches wide, ⅜ inch thick.

BOTTOM.

1 piece 24½ inches long by 11 inches wide, ½ inch thick.

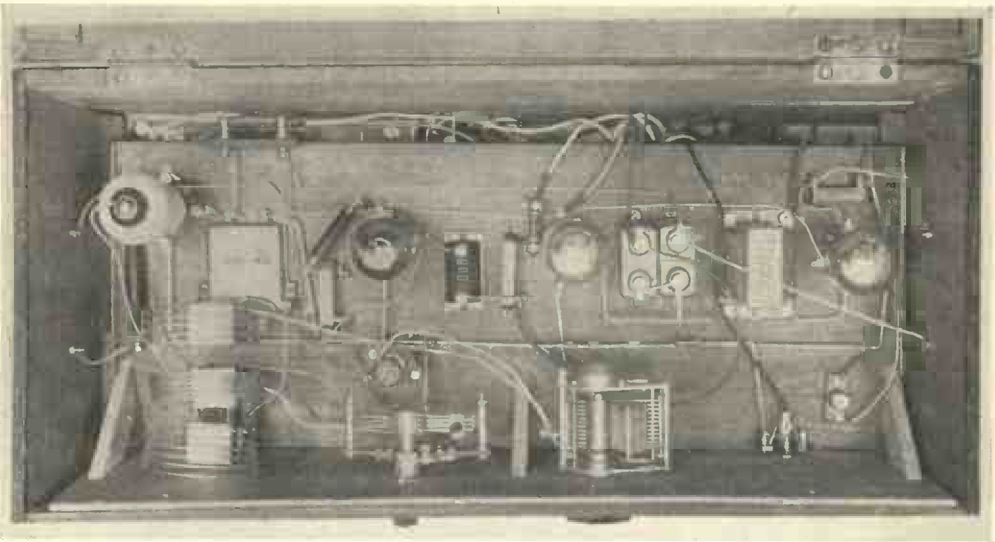


Fig. 11.—Looking Into the Set.

The cabinet is here shown with the lid opened and the complete set in place ready for reception. The battery cords can be seen leading down to the batteries in the lower compartment.

Batten.

1 piece 48 inches long by 1½ inches wide, ⅜ inch thick.

The wood should be American whitewood or yellow pine if available in the requisite width ; otherwise use mahogany-faced plywood. *Sinclair's, of Harrow.*

Sundries.

- 4 small rubber buttons for feet.
- 2 pairs small brass cabinet hinges with screws.
- 2 dozen ⅝-in. by No. 4 countersunk screws.
- 1 ounce 1-inch "panel pins."
- 1 packet oak water stain.
- 1 pint French polish.

Assembling the Baseboard and Panel

Prepare the timber for the baseboard and panel, then mark on the panel—as shown in Fig. 3—the centres of the holes for the components. Drill the holes to size, countersink those for fixing screws and clear off any roughness from the edges of the others.

Next prepare three wooden brackets as shown in Fig. 4 ; then screw the panel to the front edge of the baseboard and glue and screw the brackets to the back of the panel and to the baseboard—as shown in Fig. 5—taking care to keep the panel at right angles to the baseboard. The purpose of this bracing is to ensure an absolutely rigid structure, as vibration is apt to cause mysterious crackling noises when the set is playing.

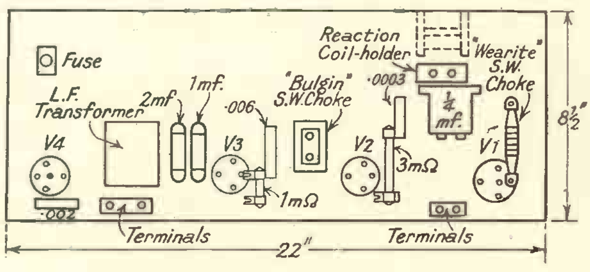


Fig. 7.—Components on Baseboard.

Screw the components to the baseboard in the positions shown.

Assembling the Components

Fix the tuning and reaction condensers with their slow-motion dials to the panel, then fix the L.T. switch and the dual plug-in coil holder to the panel.

Lay out the components on the baseboard, arranging them as shown in Fig. 7, and screw them down firmly, then make and fix the aerial choke clips—as shown in Fig. 8—and fix the "Wearite" S.W. H.F. choke between them. Next bend the grid leak clips for the grid circuit of the third valve and fix them as shown in Fig. 9, the separate clip being clamped between washers by a screw into the baseboard. Arrange the detector grid leak in a similar manner.

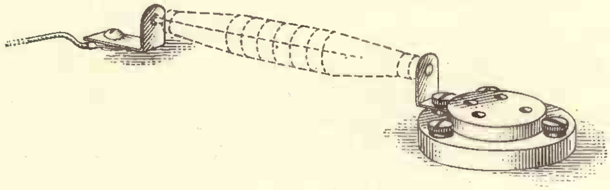


Fig. 8.—Clips for Aerial Choke.

Thin strip metal is bent to an L shape and used to connect the aerial choke coil to grid terminal of first valve and to the earth return lead.

Reaction Coil Mounting

The single plug-in coil holder should be screwed to a block of wood 1 inch high, ¾ inch wide and 2¼ inches long, as shown in Fig. 10, which should first be screwed to the baseboard about ½ inch away from the dual coil holder.

This block raises the coil and brings it into alignment with the secondary coil, the exact position should be found by trial.

Wiring up the Receiver

The wiring is quite straightforward and simple but should be carried out methodically, using glazite wiring for most of the circuits and bare tinned copper wire for the main earth return lead as several connections are soldered to it.

One matter that is of paramount importance is that every joint shall be securely made and absolutely rigid. Contact nuts and screws must be tightened up dead hard and there must not be any loose or frayed ends of stranded wires anywhere, otherwise crackling noises may be heard when the set is working.

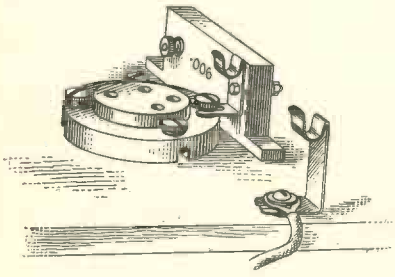


Fig. 9.—Grid Bias Connection.

The coupling condenser and leak in the grid circuit of the third valve are connected by a clip bent to fit on to the grid terminal and by another clip bent to rest on a washer on the baseboard and held by a screw which clamps the G.B.—No. 1 lead.

Short waves have an enormously high frequency and they set up sundry electrical troubles, mostly due to capacity effects. All wires carrying high frequency currents should be spaced as widely apart as possible and not be parallel to others serving the low frequency side of the circuit.

Order of Wiring

The connections should be made in the following order :—

1. Loosen the dual plug-in coil mount so that it can be turned sideways for easy access to the terminals, then fix wires of the following lengths to the stated terminals on the holder—as seen from the back.

Right-hand terminal of primary coil holder (that nearest the panel) 8 inches of insulated flexible—to anode of S.G. valve. Left terminal of same holder 8½ inches glazite wiring to H.T.+2 terminal.

Right of secondary coil holder (moving member), 9 inches glazite wiring, bared for ¾ inch at 5 inches from holder end.

Left of secondary holder, 10 inches of glazite wiring, bared for ¾ inch at 6 inches from holder end.

2. Refix the coil holder and connect the glazite wires from right of secondary to fixed plates side of tuning condenser. Left of holder to moving plates side of same condenser, leaving the end free until it can be soldered to the L.T. negative wire or earth return.

3. Run a bare copper wire straight along midway between panel and valve holders for main

L.T. negative earth return, form an eye at the right-hand end and clamp it under the S.W. aerial choke; turn the left hand in to one terminal of on-off switch. Connect with similar wire to one filament terminal on each valve holder and to the following points, using short straight wires as far as possible and soldering all joints to the main earth lead, also the glazite wire from the tuning condenser.

Earth return wire to one side of L.S. condenser; 1 mfd. condenser; 2 mfd. condenser; moving plate side of reaction condenser; $\frac{1}{4}$ mfd. condenser; one side of fuse holder.

4. Connect together one filament terminal on each valve holder with yellow glazite wiring for L.T. + supply.

5. Right-hand terminal of reaction coil holder to fixed plates of reaction condenser. Left of holder to anode of detector valve, thence to one side of Bulgin S.W. H.F. choke. Other side of same choke to free terminal of coupling condenser.

6. Anode terminal on first valve holder (screening grid of S.G. valve to $\frac{1}{4}$ mfd. condenser and H.T. + 1 terminal.

7. Connect free end of wire from fixed plates of tuning condenser to one side of detector grid condenser. Other side of grid condenser to grid of detector valve. Grid leak, free clip to L.T. +.

8. Connect 100,000 ohm spaghetti resistance between 1 mfd. condenser and terminal of coupling condenser.

9. Anode of first L.F. valve to P. on L.F. transformer.

10. Anode of second L.F. valve to L.S. terminal and to L.S. condenser.

11. Grid of second L.F. valve to G. on L.F. transformer.

12. Connect H.T. + 2 terminal to 2 mfd. condenser, thence to H.T. + on L.F. transformer, and thence to L.S. + terminal.

Check and test all connections, then put set in case and connect L.S. terminals on baseboard to terminals on case, using Lewcos rubber covered flexible wires, similarly connect the earth return wire to earth terminal on case. Connect aerial terminal on case to grid of first valve holder. Connect the seven-way battery cords as follows.

Black between on-off switch terminal and negative of L.T. battery.

Red from L.T. + terminal of third valve and + of L.T. battery.

White to free clip of grid leak on third valve holder, and G.B. negative $1\frac{1}{2}$ volts.

Blue from G.B. on L.F. transformer, and G.B. negative $4\frac{1}{2}$ volts on the P.M. 202 valve or 9 or 12 volts for P.M. 22.

Yellow between H.T. + 2 terminal and H.T. battery 120 volts.

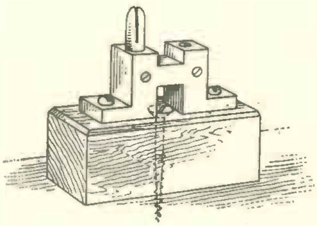


Fig. 10.—REACTION COIL HOLDER AND MOUNT.

The Wearite holder is screwed to a wood block to raise it into line with the secondary coil in the dual plug-in holder.

Brown between H.T. + 1 terminal and H.T. battery 72 volts.

Green between 1 mfd. condenser and H.T. battery 96 volts.

Finally, connect the free terminal of fuse by flexible wire to negative of H.T. battery and to positive of G.B. battery.

This completes the wiring and connections. Switch off L.T. current and remove wander plugs from batteries; then place valves in their holders, connect the anode of S.G. valve, and if a Pentode is used connect fifth terminal of valve holder to H.T. +, or connect H.T. + to side terminal of the Pentode valve.

Special Caution

Do not use the Pentode valve without adequate grid bias or it may be ruined, and never make any adjustments to bias voltage nor break the anode circuit of a Pentode valve without first switching off all H.T. voltages. Should the anode circuit be broken while the H.T. is connected to the auxiliary grid, the valve will be harmed and serious damage may be done to the set.

The batteries are housed in the lower compartment of the case—for which

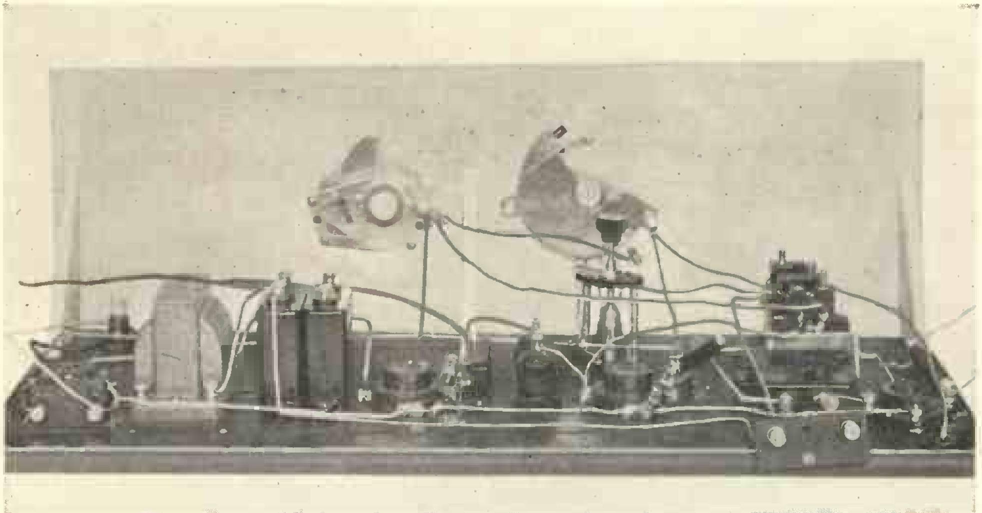


Fig. 6.—LAYOUT OF COMPONENTS ON BASEBOARD.

The base and panel are removable and this photograph shows the whole of the components assembled and wired complete.

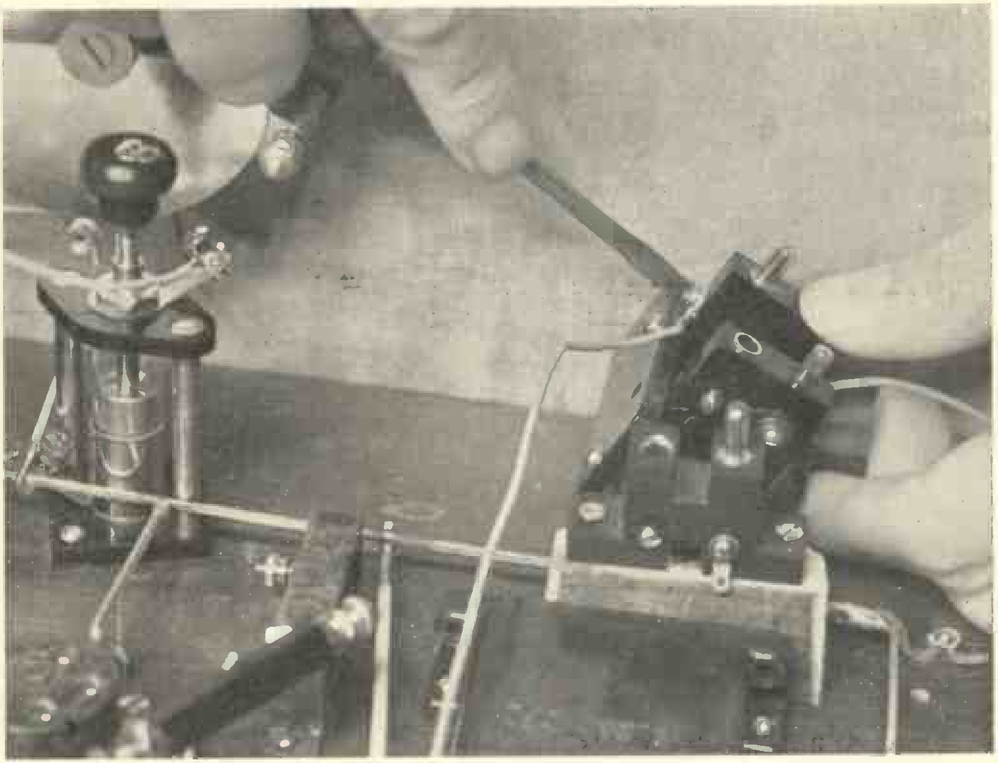


Fig. 12.—CLOSE UP VIEW OF THE COIL HOLDER TURNED SIDEWAYS TO FACILITATE WIRING.

Turning the holder sideways brings the contact screw upwards and thus makes wiring easy.

reason the Exide Gel-Cel battery is ideal, as it is unspillable.

Making the Case

The case does not present any difficulties in construction—it consists of two ends, a fretted front, hinged top, fixed upper half back, hinged lower half and a fixed bottom board.

Dimensions and shapes of all the parts are given in Fig. 13, and the timber after being prepared accordingly should be glued and nailed together in the following order:

Fix upper half back to ends and fix these to the bottom board, then fix the bearers for set to rest upon, as shown in Fig. 14.

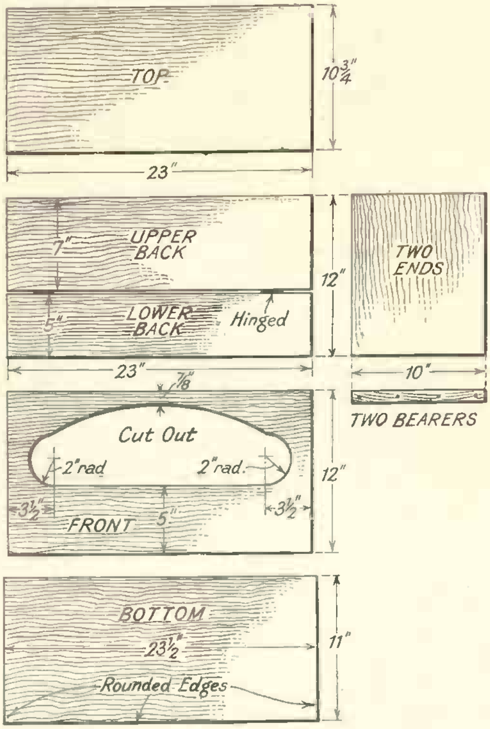


Fig. 13.—Shapes and Sizes of Parts for the Case.

Cut out the front panel with a fretsaw and clean up the edges with a spokeshave or with sandpaper.

Next fix the front piece to the ends and to the bottom, then hinge the top and lower half back. Round off all corners and edges, give the whole a rub down with fine sandpaper, then apply a coat of water stain. When it is bone dry, brush it all over with French polish, rub down lightly with fine sandpaper and finish off by polishing in the usual way with the French polish. Fit the terminals to each end of case for loud speaker or headphone leads and to aerial and earth leads, and screw the rubber buttons to the bottom corners of case to act as feet.

Handling the Set

The actual set as here described works extremely well, is quite stable and regularly brings in the most interesting American stations—mostly at loud speaker strength when conditions are reasonably good.

The newcomer to short-wave work must not expect to get these results merely by switching on and turning the knobs. At first nothing will be heard, later a vast number of Morse stations will be picked up, then—when some experience in handling the set has been acquired — the telephony stations will come rolling in at great strength, remarkable clarity, purity, and with real entertainment value.

This difficulty of acquiring the knack of tuning is not confined to this particular design, it is common to most short-wave sets and is merely due to the fact that the extraordinary high frequencies of these transmissions makes the tuning seem to be amazingly sharp.

How to Begin Tuning

A good time to begin trying out the set is about seven or eight o'clock in the evening—there is plenty of Morse about and several good broadcast stations at work, later—say, between ten o'clock and midnight or later, the most interesting American stations are more easily receivable or will have commenced working.

The aerial used for ordinary reception can be used—if it is not too long, and the S.W. set can be used with headphones, while another set is playing from the same aerial and earth.

The earth lead from the S.W. set must be as short as possible and go directly to a good earth.

Put a No. 4 coil in the primary holder,

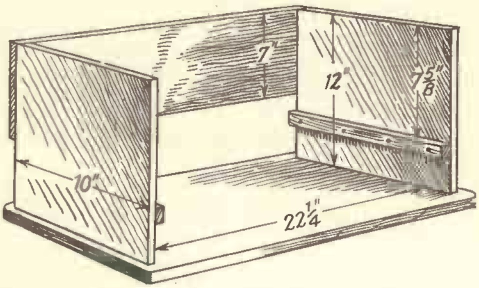


Fig. 14.—SECOND STAGE OF ASSEMBLING THE CASE.

The ends and upper half back are here shown fixed to the bottom board, also the bearers on which the set rests.

a No. 6 coil in the secondary holder, and a No. 4 in the reaction holder.

Turn both condensers to zero, that is, so that moving plates are disengaged, then adjust the coil holder so that all three coils are equidistant.

Switch on, and then if the set is not oscillating, gently turn the reaction knob slowly until a distinct rushing noise is heard in the headphones. At first it is best to use headphones, later on the set can be tuned on the loud speaker direct.

Adjustment of Reaction

It should not be necessary to turn the reaction knob far before the set goes into oscillation, but if it does not do so, then gently adjust the knob of the coil holder mount to bring the secondary coil nearer the reaction coil, or *vice versâ*.

Now turn the tuning condenser knob *very, very slowly*, and at the same time adjust the reaction by turning the reaction condenser knob to keep the set just in the oscillating condition.

Continue until the tuning condenser is fully engaged, by which time the reaction condenser also will probably be almost fully engaged and the set still just oscillating. Should the set go out of oscillation, try very slight readjustment of the coil—either nearer to, or further away from the reaction coil, or in very stubborn cases increase the H.T. + voltage to the detector valve or vary the grid biassing of the third valve.

Tuning in a Morse Signal

Having found out how to keep the set oscillating over the whole range of one set of coils, commence searching in earnest for signals, remembering to keep the set just on the oscillation point but not any more so than is absolutely necessary.

Work backwards this time, turning the tuning condenser knob very, very slowly, and listening for the whistle of a carrier wave.

The instant this is heard, stop all movement of the knobs, then very cautiously move the tuning knob, the amount will scarcely be perceptible but the note of the carrier wave will change—tune it carefully to the silent point, that is, so that whichever way the knob is turned the note rises in pitch. Now reduce the reaction by turning the knob backwards, which will cause the carrier whistle to change in pitch, continue until the note of the Morse transmission is clearly and definitely heard, which will probably call for minute readjustment of the tuning condenser.

Test every carrier wave in the same way until a telephony or broadcasting station is heard.

Tuning in a Broadcast Station

The same procedure has to be adopted when a broadcast station is first picked up. There is a difference in the sound of the carrier wave which will soon be appreciated, but in this case it is necessary to turn the reaction condenser knob until the set just goes off the oscillation point and at the same time keep the tuning condenser so adjusted that the silent point of the carrier wave is constantly maintained. Speech or music will then come in suddenly, clearly and strongly, and can be built up gradually to full strength by very careful manipulation of the reaction condenser.

Note the dial reading of the tuning condenser and the numbers and order of the coils so that the same station can be tuned in again without much searching. If it is an American station the name and call sign will be announced once every fifteen minutes and it is generally advisable to listen in until such announcement is made, as this definitely identifies the station.

Announcements are made by foreign stations but they are not easily distinguished, as they are mostly in foreign languages, sometimes in unintelligible native tongues.

Wave Range of Tuning Coils

The nominal wave range of the Atlas tuning coils is as follows, when used in the secondary circuit.

No. 2.—15 to 25 metres.
No. 4.—20 to 50 metres.
No. 6.—35 to 75 metres.
No. 9.—45 to 100 metres.

Some stations may be received on two different coils; when this happens use the combination that gives best results, that is, generally, the largest coil.

Dial Readings

A few characteristic coil arrangements and tuning condenser dial readings for some American and other stations received at loud speaker strength are given below as a guide for the beginner. Many other stations are of course received, some of small entertainment value, while others give excellent programmes.

The Neutralising Condenser

Reference to the circuit diagram shows a small variable condenser in series with the aerial. This is a very low value "J.B." neutralising condenser, and will prove helpful under some conditions, especially when the aerial is rather on the long side.

In other cases it may be omitted from the aerial circuit, and may then be shunted across the tuning condenser and used for the ultimate fine tuning of a station. When this is done it is helpful to extend the control spindle on the condenser so that the knob is just below the level of the top of the cabinet where it is easily accessible by raising the lid.

Still another use for the neutralising condenser is to shunt it across the reaction condenser and use it for fine adjustment of reaction.

This was done in the test set shown in the photographs and proved quite useful although not essential. In practice it was found that not more than one-eighth of a turn was necessary to give the finest control of reaction.

Tested on a poor aerial and very indifferent earth, the next larger reaction coil had to be used to keep the set oscillating freely and under these conditions the auxiliary reaction condenser was most effective.

Alterations to the reaction coil, or to the primary coil do not greatly affect the dial readings given here, but differences in efficiency of the actual aerial and earth connections may make the readings vary half a degree or so, but in any case, if the specified components are used the set will bring in all the worth while stations in a very satisfactory and reliable manner.

Conditions of reception vary a good deal from day to day, but the stations named have been picked up regularly night after night at the stated settings. Coil A is primary, coil B secondary, coil R reaction.

Station.	Call Sign.	Country.	Coil.			Dial.
			A.	B.	R.	
Chelmsford .	G5SW	England	2	4	4	83
Madrid .	EAQ	Spain	6	4	4	122
Rome .	2RO	Italy	6	4	6	81
Radio-Coloniale .	Pontoise	France	6	4	6	86
Springfield .	W1XAZ	U.S.A.	6	4	6	130
Schenectady	W2XAF	U.S.A.	6	4	6	133
Boundbrook	W3XAL	U.S.A.	4	6	4	140
Pittsburgh .	W8XK	U.S.A.	4	6	4	152
Moscow .	RW59	U.S.S.R.	4	6	6	158
Bowmanville	VE9GW	Canada	6	9	4	72
Pittsburgh East .	KDKA	U.S.A.	6	9	4	71
Prague .	—	Poland	4	9	6	118

LOCATING FAULTS IN HOME CONSTRUCTED RECEIVERS

By FRANK PRESTON, F.R.A.

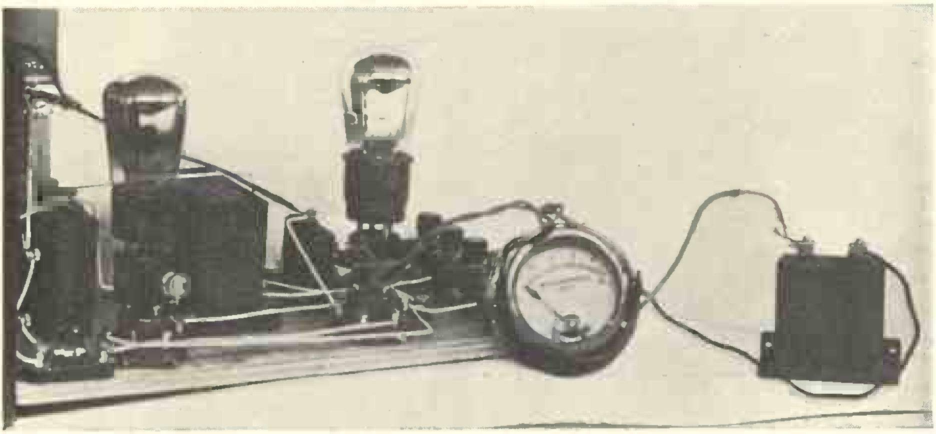


Fig. 1.—Two Useful Pieces of Apparatus for Finding Faults.

A valve filament tester is shown in the valve holder on the left, and a split anode adaptor (connected to a milliammeter) on the right.

THE object of this article is to show how a thorough examination can quickly be applied to a wireless set so that any and every form of trouble can be " spotted " without the use of costly or elaborate apparatus.

The tests to be described apply equally well to a set which has just been completed as to one which has been working correctly but has developed a fault.

Externals

Before testing the receiver proper it is always advisable to check over the " externals," that is the aerial and earth leads, power supply and loud speaker.

Faulty Aerial Lead

A bad connection in the aerial lead is generally evidenced by very weak signals, or by crackling sounds. The latter occur most when the aerial is being blown about in a wind or when the lead-in is shaken. To make quite certain that the crackles really originate in the aerial, disconnect the lead-in wire from the set, when they should cease. If this has no effect, it is obvious that the source of trouble is elsewhere.

Faulty Earth Connection

An unsatisfactory earth connection generally causes a certain amount of instability ; reaction is " fierce," and/or hand capacity effects are troublesome. It is often found in the case of a buried earth-plate that the lead has come adrift due to corrosion. In such an instance the lead should be re-soldered and the joint covered with paint or varnish to prevent subsequent deterioration of the contact. With a " water-pipe " earth, oxidation of the pipe causes a poor contact, and the cure is to scrape the pipe clean and bright before attaching the clip again.

Testing L.T. Batteries

All tests to batteries should be applied whilst they are under load, or, in other words, when the set is switched on. The accumulator can be tested with a hydrometer (to measure the acid density), with a voltmeter, or even with a flash-lamp bulb. In the latter case the bulb should light with equal brilliance when the set is switched "on" as when it is "off."

Testing H.T. Batteries

The best way to test a high tension battery is to measure the voltage between each tapping point. This is much better than measuring the total voltage, because it detects any faulty set of cells, which can easily be short-circuited. The sum of the voltages between each set of tapping points should be no less than half the rated battery voltage; if it is less the battery should be scrapped as useless.

The voltmeter should for preference be of a high resistance pattern, but if it is not, keep it in circuit for only an instant because it will absorb more current than the battery will safely give. In the case of a battery having 3-volt or 6-volt tappings, the various sections can be tested with reasonable accuracy by means of a flash-lamp bulb. Here again contact should be made only for a second or so.

Testing Voltages of H.T. Eliminator

When a H.T. eliminator is employed the voltages at the various tapping points can be tested only with a good *high resistance* voltmeter. The set must, of course, be switched on, otherwise readings will be much higher than normal.

Testing a Loud Speaker

The loud speaker is tested by connecting one lead to the positive terminal of an accumulator cell and touching the other lead against the negative terminal. There should be two distinct "plops," one when the wire touches the terminal and another as the circuit is broken. In the case of a low resistance speaker used in conjunction with an input transformer, connection should be made to the primary terminals of the transformer, and not to the speaker itself.

TESTING THROUGH THE SET

Once the external components are known to be in good condition, the set itself can be tested with more confidence. When everything seems "dead," and no sounds of any kind can be heard, first of all disconnect one loud speaker lead; there should be a distinct click in the speaker. If not, the last valve is passing insufficient high tension current. This might indicate (1) a faulty output valve, (2) a burnt-out H.T. fuse, (3) bad contact in H.T. or L.T. circuits, or (4) too high grid bias voltage.

Valve Tests

It is rather difficult to test the valve directly without apparatus, but the same result can be obtained by testing for H.T. between the anode socket and one filament socket (or cathode socket in an A.C. set) of the valve holder, and by testing for L.T. between the two filament sockets (by means of a voltmeter or bulb). Lack of H.T. indicates a faulty connection in speaker and battery circuit, whilst absence of L.T. generally points to a faulty battery switch. The switch can be checked by short-circuiting it with a short length of wire.

Using a Valve Tester

It is easy to find whether or not the valve filament is intact by connecting a bulb in series with the lead to one filament terminal, or better still by using a special valve filament tester such as is made by Messrs. Bulgin (see Fig. 1). The valve is replaced in its holder by the tester and is then plugged into the latter. Failure of the bulb to light shows the valve to be burnt out.

What to do if H.T. Supply is not Reaching Valve

When the last valve is functioning correctly, work backwards and apply similar tests to those already described to the other valves. If it is found that a valve is not receiving any H.T. supply it can safely be assumed that the component in its anode circuit (choke, resistance, transformer, primary, etc.) is at fault, and this should be tested in the manner to be described later.

Anode Current Tests

In addition to the tests already mentioned, much can be learned regarding the faults existing by measuring the anode

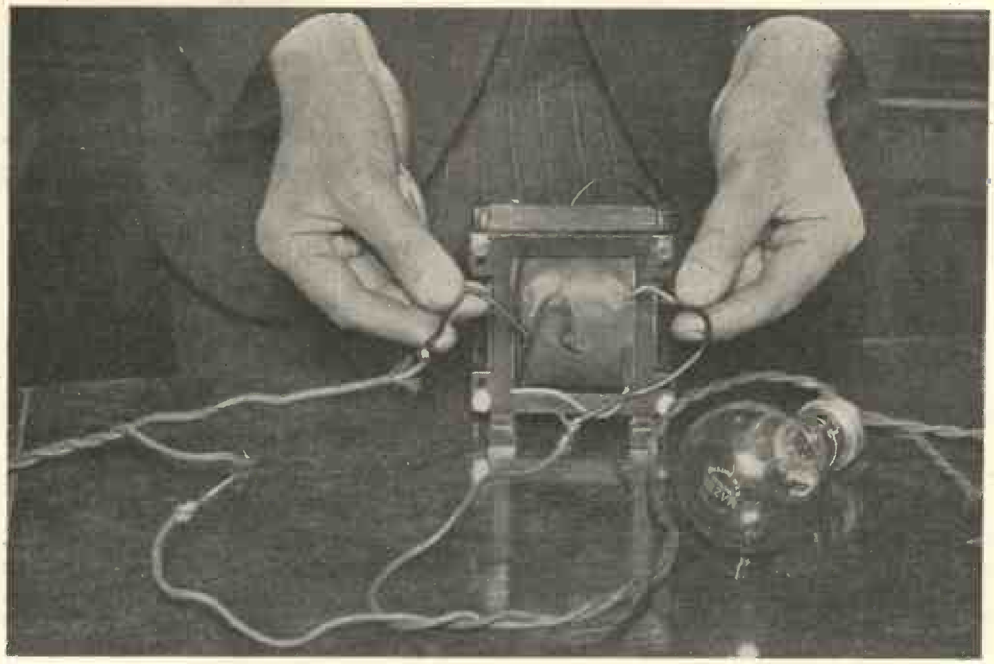


Fig. 2.—How to Test the Primary Winding of a Mains Transformer by Putting a Lamp in Series.

If the lamp glows, the primary winding is continuous.

Fig. 3.—Testing the Condition of a Valve with a Milliammeter in the Anode Circuit.

The test should be made in the anode circuit of each valve in turn. A large increase, or fall to zero, of anode current when signals cease will be indicated if a low frequency valve is faulty. A smaller change will be indicated in the anode circuits of the other valves if one of these is at fault.

current passing through each valve. This can be done by connecting a milliammeter in series with the anode lead. As, however, the meter will probably offer a fairly high impedance to high frequency impulses, it is advisable to connect a 1 mfd. condenser in parallel with it. The meter can be connected between the anode terminal of the valve holder and the wire normally going to it, or to the terminals of a specially made split anode adaptor, as shown in Fig. 1.

The adaptor, which is also made by Messrs. Bulgin, is used in a similar manner to the filament tester previously mentioned.

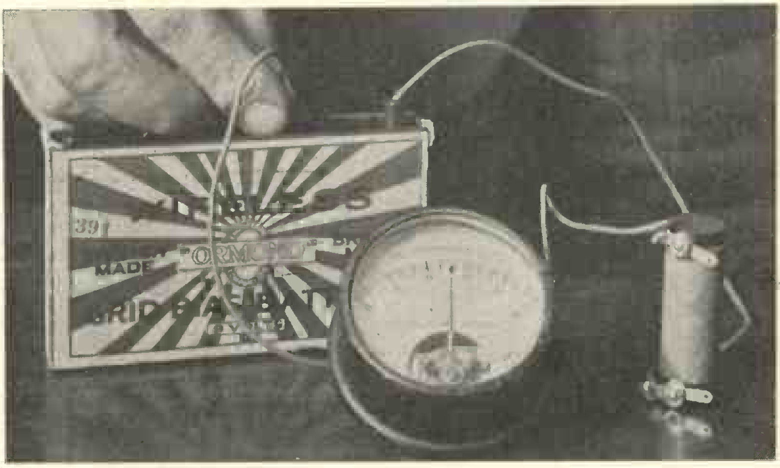


Fig. 4.—Testing a High Frequency Choke for Continuity with Battery and Milliammeter.

Before taking measurements, tune the set so that no signals are being received, in order to avoid false readings. The measured currents should be compared with those given by the valve makers for the particular supply voltages in use. If the needle of the meter flickers there is a bad contact, or the anode circuit component is faulty, giving intermittent contact.

What the Readings Show

Too high a reading shows (1) insufficient grid bias, (2) grid bias battery connected wrong way round (*i.e.*, positive to negative), or (3) a break in the grid circuit. In regard to (2), one must not overlook the possibility of the battery being wrongly marked by the makers, for such a mistake has often come to the writer's attention.

Too low a reading means either (1) the valve has lost its emission (generally due to age), (2) the grid bias voltage is too high, or (3) a by-pass condenser is short-circuiting the supply.

The Detector

If the anode current readings in each case prove to be quite normal, it is safe to assume that the valves, filament circuit and anode circuit components are all satisfactory. Any faults must therefore be confined to the tuning or detector circuits. Of these the detector is more likely to be wrong, and as this is the most important part of the whole instrument, even a slight fault might cause complete silence.

Unsuitable H.F. Choke

An unsuitable high frequency choke might prevent the valve from oscillating, but in that case signals should still be received, although at poor strength. The only satisfactory way to check the choke is to replace it by another one, because although it will pass the H.T. current properly its inductance might be too low. As a matter of fact, this is a very common fault with many of the low-priced components. In many cases the choke has sufficient inductance for medium wave reception, but is useless on the long-wave band.

An internal short circuit in the detector grid condenser will almost invariably prevent oscillation and entirely stop reception, whilst a broken connection will cause signals to be very weak, and will in most cases prevent oscillation. Tests for fixed condensers will be given later.

Faulty Grid Leak

The grid leak is not a very critical component, but nevertheless a poor one can be the cause of continuous crackling. In some cases, also, a faulty leak will cause a recurring " plop-plop-plop " sound due to the charge on the grid building up and leaking away across the condenser instead of through the grid leak.

Coils

It is very unlikely that the tuning coils will be faulty unless they have been badly handled, but if any one is suspected, its windings can be tested as described below. With screened coils having detachable covers it is not infrequent to find the leads shorting to the screens due to the insulation being scratched away by removing and replacing the covers. A short at this point would cause the fuse to blow frequently, or would prevent the reaction control from having any effect. A more frequent cause of trouble in the tuning system is a faulty switch arrangement. Where ganged switches are employed, especially with the older types of coils, it is sometimes found that one switch contact has become strained so that it is inoperative. This generally causes reception to be poor on one waveband, although quite normal on the other.

Tuning Condensers

When crackling sounds are heard as the tuning condensers are operated, there is either a bad contact to the moving vanes, or the two sets of vanes are touching at certain points. Touching vanes can generally be detected by inspection, and the fault can be cured by adjusting the lower spindle bush or by bending the vanes very carefully with the blade of a knife. A bad contact will be found to be due to a broken " pigtail " connection or to corrosion of rubbing surfaces. The cure is obvious in both cases.

Distortion

In addition to the more or less " electrical " tests referred to above, there are others which require to be applied in cases of distortion, unsatisfactory reaction control, etc.

Before prescribing means of detecting the latter forms of trouble, the writer must assume that the general design is sound or that some good constructional article or chart has been followed.

Likely Causes of Distortion

Distortion usually points to (1) low-frequency feed-back, (2) faulty L.F. valve, (3) wrong values of grid bias, and/or high tension voltage, (4) overloading of valve or speaker.

Fig. 5.—Cutting out a Screen-Grid Valve by removing the Aerial Lead from its Normal Terminal and Connecting it to the Anode Terminal of the S.G. Valve.

How to Detect Oscillation of L.F. Valves

Fault (1) generally causes one of the L.F. valves to oscillate. Oscillation can be detected by touching the anode terminal with the moistened finger; if oscillation is taking place a " plop " will be heard in the speaker, and there will be a change in anode current. Bad arrangement of L.F. transformers or insufficient de-coupling of anode circuits will cause the feed-back, and it is sometimes possible to effect a cure merely by altering the position of one transformer. The best position can most easily be found by

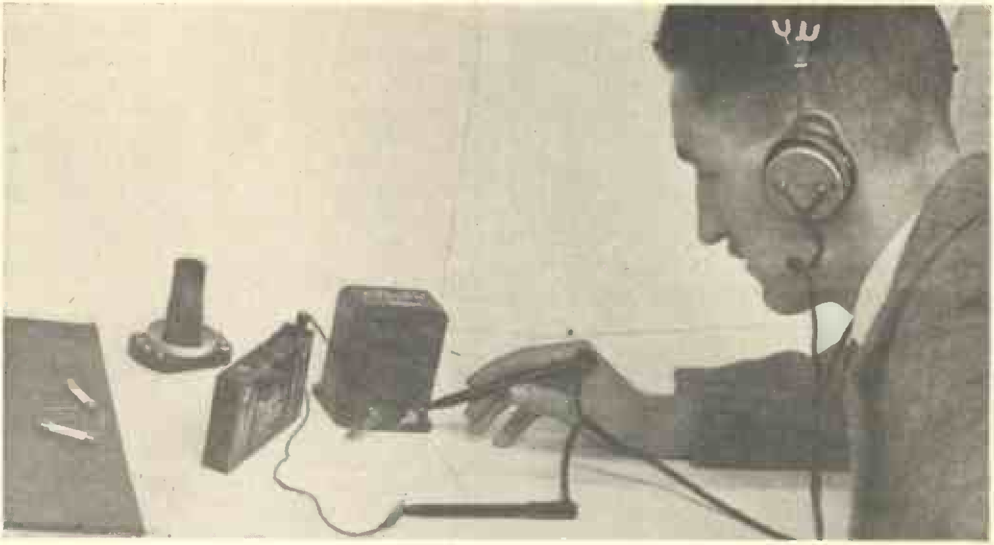


Fig. 6.—METHOD OF TESTING TRANSFORMERS, CHOKES, TUNING COILS, RESISTANCES, ETC. FOR CONTINUITY OF WINDINGS.
Crocodile clips provide a quick and handy method of making connections.

substituting short lengths of flex for the normal transformer leads and orientating the transformer until the best position is found. It might be mentioned in passing that this test is often helpful in curing hum in an all-mains receiver.

A Test for a Faulty L.F. Valve

An L.F. valve which has become " soft," or which is losing its emission, will cause distortion, making reproduction thin and " tinny." Substitution of a new valve is the best test, but where this is impossible, the suspected valve can be changed over with the detector valve for the purposes of trial. If the valve is wrong, it will probably be difficult to make it oscillate when in the detector socket.

How to Detect Overloading

Overloading is indicated when reproduction is reasonably good at low volume levels, but deteriorates as the volume is increased. When overloading does occur, it can usually be traced to the last valve. A cure can be effected by increasing the high tension and grid bias voltages or by substituting a larger power valve. If the receiver is situated very near to a broadcasting station, the first valve might in some instances be overloaded, but that is fairly uncommon. The most satisfactory cure is to fit some type of aerial input control, such as a small pre-set series aerial condenser.

To ascertain if any particular valve is being overloaded, connect a milliammeter in its anode circuit. The needle should remain reasonably steady, but if it gives a series of violent " kicks," one can be pretty sure that the valve is unable to deal with the signal strength applied to it.

Overloading of a Loud Speaker

If the speaker is of a fairly modern type, it is unlikely that it will be overloaded by the input from the average three or four valve set unless it is connected directly in the anode circuit of a super power valve. In the latter case it is quite possible for the magnet system of a balanced armature type of speaker to become " saturated " due to the heavy D.C. current passing through its windings. Under such circumstances the cure is to employ choke-capacity or transformer feed, so as to isolate the windings from the D.C. current.

Localising the Fault

Before applying any of the tests so far mentioned, some experimenters might prefer to " localise " the source of trouble by cutting out each valve in turn. This is a very effective method where it can conveniently be applied.

Putting H.F. Valves out of Circuit

The procedure in the case of H.F. valves is as follows: Remove the aerial lead from its normal terminal and connect it to the anode terminal of the first valve. This eliminates the first valve, because the aerial then feeds directly into the grid circuit of the second. Any number of H.F. valves can be put out of circuit in turn by transferring the aerial lead from one to the other.

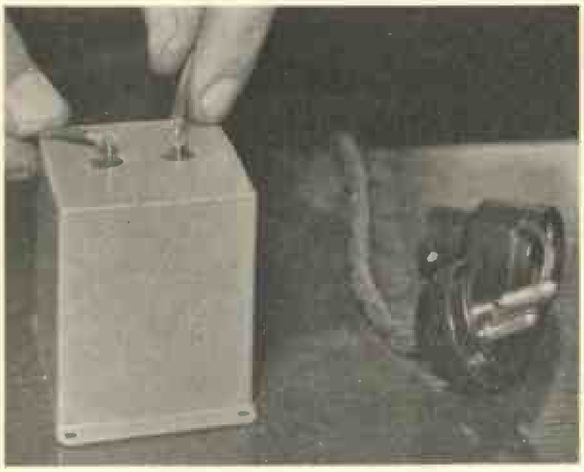


Fig. 7.—Testing a Large Capacity Condenser (1).
The condenser should be charged up from a D.C. supply of, say, 100 volts, leaving it for five minutes and then bridging the terminals with a screwdriver (see below).

Putting L.F. Valves out of Circuit

Low frequency valves can also be put out of circuit by moving the speaker leads from one anode circuit to another. The leads should simply be connected in parallel with the resistance, transformer primary or choke in the anode circuit of individual valves. It will be seen, of course, that when all the L.F. valves are out of circuit (speaker leads n detector anode circuit) the power will not be sufficient to operate a loud speaker properly, so it is much better to use a pair of phones.

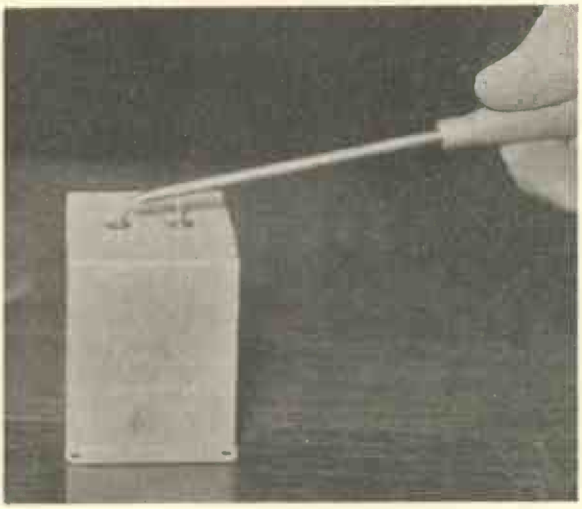


Fig. 8.—Testing a Large Capacity Condenser (2).
A spark should be obtained when the terminals are bridged with a screwdriver (see Fig. 7).

This method of isolation is particularly useful in tracing the origin of crackles and similar annoyances.

MAINS SETS

All the above experiments apply to either a battery or mains receiver, but there are certain additional tests which are necessary in sets of the latter type.

It need scarcely be mentioned that in dealing with a mains set, the utmost caution must be exercised, or a nasty electrical shock is bound to be experienced. In fact it is always advisable to switch off the supply before touching the inside of the set.

Mains Hum

The most frequent source of trouble in mains sets is "hum," of which there are two distinct kinds. The first is pure mains hum, which can be heard immediately the set is switched on, and the second, modulation hum, which is only heard when the set is tuned-in to a signal.

Mains hum

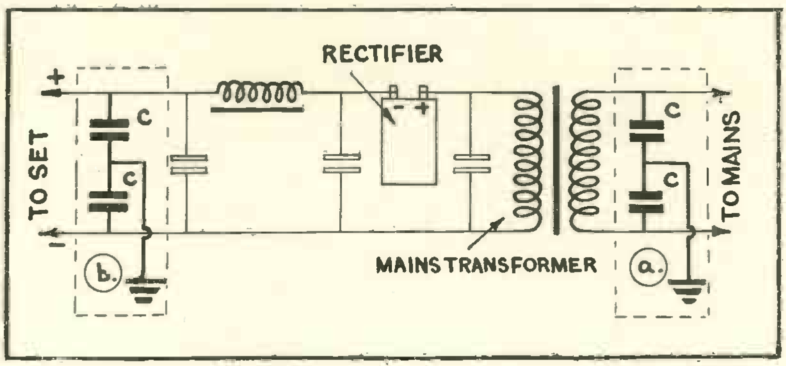


Fig. 9.—METHOD OF CURING MODULATION HUM.

merely indicates lack of smoothing, and can be cured by using a larger smoothing choke or more smoothing condensers.

Modulation Hum

Modulation hum can often be traced to a poor earth lead, but sometimes the complaint is more involved. When the earth lead is efficient, a cure can in most cases be effected as shown at (*a*) or (*b*) in Fig. 9. In each case a pair of high test-voltage condensers of ·01 mfd. capacity (marked C) are wired in series across the supply, and the series connection is joined to earth. It is of interest to note that two or three firms now supply a unit, consisting of a pair of suitable condensers mounted together in one case, especially for this purpose.

When a mains set which employs valve rectification is in use a falling off in volume can often be traced to an old rectifying valve which is losing its emission. The only satisfactory remedy is to replace the valve.

TESTING INDIVIDUAL COMPONENTS

When any particular component is suspected, it is best to remove it from the set and give it a thorough test. The methods of testing different components are explained briefly below, and some of them are illustrated in the accompanying photographs.

Windings of Transformers, Chokes, Tuning Coils, Resistances, etc.

Connect one terminal of a small battery to one end of winding under test, connect one phone lead to other battery terminal and touch second phone lead against the other end of winding. A loud click should be heard both as contact is "made" and "broken." The click will naturally be weaker when testing a resistance of high value.

In the case of a transformer or iron cored choke, a similar test should also be applied between one terminal of each winding and the core; only the very faintest single click should be heard.

Fixed Condensers

Charge by applying a voltage to the terminals, allow to stand for some time, and then connect a pair of phones to the terminals. A loud click should be heard indicating that the condenser has held its charge.

The choice of a suitable charging voltage depends on the capacity of the condenser under test. For a 2 mfd. condenser 4 volts will be ample, whilst up to 100 volts would be necessary for a capacity of, say, ·0001 mfd.

In applying these tests neither the condenser terminals nor phone leads should be touched with the fingers, or the charge will leak away through the body.

To Measure Resistances

Connect in series with battery and milliammeter. If the battery is arranged to have a voltage of 1 for every 1,000 ohms, a reading of 1 milliamp. should be given; *e.g.*, a 2-volt battery with a 2,000-ohm resistance should give a reading of 1 milliamp.

Alternatively, any battery voltage might be applied to any resistance, and the value of the latter determined from the formula:

Resistance (in thousands of ohms) equals Battery Voltage divided by Current (in milliamperes).

RECENT DEVELOPMENTS IN AMATEUR TRANSMISSION AND RECEPTION

By LESLIE McMICHAEL A.M.I.E.E.

(Founder and Vice-Chairman of the Radio Society of Great Britain; Chairman, Radio Manufacturers' Association)

THE radio amateur, whether he specialises on the receiving or transmitting side has been subjected to a varied career. He has been lionised, he has been pilloried, he has been acclaimed as a man of standing, he has been castigated in the Press, and yet throughout it all he has, to his credit, kept an even keel.

This is said in no boastful spirit but merely to indicate that life for him has been, and no doubt still will be, one in which the "pendulum swings" were most marked.

If such a thing were possible I would try to kindle still further the enthusiasm among the vast band of wireless amateurs which represents a brotherhood almost unequalled in its international aspect.

The Very Early Days

Cast your mind back to those very early days of wireless when the sight of an aerial in your back garden made your neighbours think you were heading for the first stages of imbecility.

Then there was the burning of the midnight oil by the intrepid band of transmitters who tapped Morse keys far into the night in their memorable efforts to annihilate space by wireless signals. To these, my old friends, I say—

Did you find an officialdom sympathetic towards your burning of the midnight oil? No! For after giving you a wavelength allocation measured in thousands of metres necessitating the winding of coils consuming thousands of yards of wire, the only thanks you received was the curt information that you were interfering with official wireless services. That meant that you must be relegated to the other end of the wavelength scale, the short waves, everyone thinking that the difficulties of establishing communication on a "few metres" would be insuperable. But what happened! Why you just rolled up your sleeves and redoubled your efforts to find the solution to the mysteries of wireless.

That your work in this direction marked an epoch in wireless transmission redounds to your credit. You literally spanned the world, thought nothing of conversing with American cousins or chattering with a brother wireless enthusiast in the antipodes.

What were the Results?

Was the result of all your efforts and achievements carried out for the sheer love of this fascinating science without any thought of financial gain, for you were amateurs in the true sense of the word?

You have the satisfaction of knowing that the tardy officialdom has reaped the benefit of your pioneer work, and as we all know, short wave commercial stations are in daily use throughout the world.

You have fostered and furthered the cause of wireless, helped in the establishment of commercial radio, made possible the present efficiency of wireless broadcasting and collectively contributed data which has been invaluable in fathoming the cause of "fading" and similar problems.

Developments which have taken place

With every justification you are proud of the results of your work, but for the benefit of those new to the science I want to deal a little more fully with the developments which have taken place.

The vast subject of wireless is interesting both to the passive listener and the active experimenter.

On the one hand are those who, after the day's work is over like to sit by the fire or in the shade of the garden, according to the time of year, and enjoy the excellent programmes provided by the B.B.C. without troubling too deeply about the why and the wherefore.

On the other hand, there are many enthusiasts who regard broadcasting rather in the nature of a necessary evil, which interferes with their research and who, naturally, take more delight in the signals from the other end of the earth, be they distinct or indistinct, than in the most perfect reproduction of sounds from the near-by broadcasting stations.

MR. LESLIE MCMICHAEL, A.M.I.E.E., A.M.I.R.E.

Founder and Vice-Chairman of the Radio Society of Great Britain; Chairman, Radio Manufacturers' Association.

It is to these technical enthusiasts, the real amateur in every sense of the word, that the mere listener is largely indebted for the wonderful rendering of human and musical sounds, which he can now enjoy with so little expenditure of energy and at the same time so little cost.

Pre-war Wireless Amateurs

The pre-war wireless amateurs were an intrepid band of pioneers who made up in zeal what they lacked in numbers. The apparatus was large and cumbersome and worked only after the acquirement of infinite skill and patience. Remember that the signals available were only of the Morse variety, but the "ether explorers" maintained their enthusiasm, and although the work accomplished was real "spade work," nothing of real outstanding character can be recorded beyond the important fact that hundreds of these pre-war amateurs offered themselves to the services in the early part of the war and their training and knowledge was of great value. Indeed, many of them quickly rose to important posts, and not a few remain to-day in the signals and technical branches of the Navy, Army or Air Force. The war provided the much needed fillip to wireless. Valves were developed and wireless telephony introduced and gradually perfected, though of course, not by any means as we know it to-day.

The "Experimental Licence"

Up to the end of 1922 the only wireless licence available was the "Experimental Licence," the same licence that has been in force for a number of years and which was only granted to applicants who could satisfy the Postmaster-General that they were *bonâ fide* experimenters.

It is estimated that before broadcasting had begun the number of licences in force did not exceed 1,000. Small wonder that those early enthusiasts still living should be proud to be numbered among the "originals."

The Present Broadcast Licence

Quite a long story could be written of the changes that were wrought when the "Interim Licence" was introduced to meet the situation, whilst the final form of broadcast licence was still under consideration, this being coupled with the constructor's licence, intended for people who wished to build up their own receivers. When the present broadcast licence was introduced in July, 1924, it took the place of the licences first mentioned and the increase in the number of these licences has been phenomenal. At the time of writing the official figure is nearly five millions, and saturation point is a long way off.

A Year of Remarkable Achievements

Reverting for a moment to the true radio amateur as distinct from the ordinary listener, it must be put on record that the year 1924 will always stand out as the year of such remarkable achievements that even the most optimistic amateur experimenters of the day could never have foreseen or imagined.

Long Distance Communication by Amateurs

First of all mention must be made of the astonishing results obtained in long-distance communication by amateurs with small power transmitters on short wavelengths. It had been customary to conduct tests between amateurs in this country and those in America. Prior to September, 1923, however, all attempts to reach America from *this* side had failed, although a large number of American amateurs had been heard in this country. In that month a change was noted and certain vessels off the coast of America reported hearing English signals on the short wavelengths. Then in November, 1923, a French amateur established for the first time two-way working with America and by January, 1924, no less than nine British amateurs were in more or less constant touch with Canada and the U.S.A.

Two-way Communication between England and New Zealand

In October of 1924 we had the culminating achievement of that year for long-distance working when two-way communication was definitely established between England and New Zealand. The names of Goyder, Simmonds, Marcuse and Partridge are associated with this feat, all English amateurs, and they provided evidence and data of the efficiency of short wave transmissions which caused a modification of the then existing theory of the propagation of these short waves.

In November of 1924, Australia was "worked," and one of the predominating influences for good in all this activity was the Radio Society of Great Britain, with its energetic and active transmitter and relay section. This good work was continued over the next two years with interesting experiments on 20 metres, research on speech, distortion and fading, and the increasing popularity and importance of quartz crystal control should be recorded.

Progress in Receiver Designs

So far as ordinary receiver design was concerned, it should be noted that the introduction of the screened grid valve at about this period simplified high frequency amplifier design and marked a milestone on the steady road of progress, which has continued to the present day. Most amateurs also evinced a growing interest in all forms of battery eliminators, or, in other words, were experimenting towards running their receivers from the electric light mains. With the arrival of valves with independently heated cathodes, the elimination of both H.T. and L.T. batteries became practicable. Then again the opening of the first of the Regional Stations—5 GB. centres interest on the problem of selectivity of simple receivers.

A solution to this was the inclusion of a simple form of wavetrap. This did not get to the real heart of the trouble, however, and the screened coils and transformers previously employed tended to become obsolete in favour of a complete screening box. Aerials were simplified with an aim at getting the greatest effective height and a reduction of wires and length.

Developments in the Design of Condensers

Another phase of development which followed closely was the design of the variable condenser. " Low loss " was the cry for quite a long period and then we saw " straight line capacity " giving way to " straight line wavelengths " and followed by " straight line frequency." The last two types were open to criticism and eventually there was evolved that happy medium—the " logarithmic condenser." These are still with us and have brought about identical readings on the two or three tuning scales.

Ganging

With coils becoming more accurately matched for inductance and condensers boasting of a capacity variation which followed a given law, within narrow limits, it was found possible to gang them together. In this way one tuning control became the popular demand and led to a reduction of controls on the receiver panel instead of the multitudinous knobs which adorned the early sets, and station-getting became rather the privilege of the expert. Within the last year or two desire for quantity has given place to quality, but with the high degree of selectivity consequent on a station-crowded ether steps had to be taken to explore ways and means to produce the " knife edge " tuning without impairing the overall performance of the receiver by a failure to pass the complete range of frequencies on which, of course, quality of reproduction depends.

A popular method for this has been the " band pass," and sets using this scheme are becoming popular. The amateur appetite is far from satisfied, however, and progress in improvement is inevitable.

Value of the Amateur

Some time ago a well-known editor passing judgment on the amateurs, pointed out how they had constituted themselves research workers by the hundred thousand and through the furnace of their criticism has passed every published idea, system and component that has been placed on the market. No manufacturer, however rich and conscientious, would, or could have afforded, the vast experimentation which the general amateur public has voluntarily provided.

The manufacturers do not always look kindly upon them but undoubtedly they owe them a big debt, for a body of expert criticism and practical comment has been made available which has aided the manufacturer in eschewing the bad and developing the good. Short-wave work is, perhaps, the crowning example. Their enthusiasm and zeal for work enabled the amateurs to prove to the broadcasting authorities and to the professional wireless engineer throughout the world that short waves as a means of transmission and reception over long distances had great inherent advantages. They had been primarily responsible for the latest improvements by bringing about the elimination of those features of design and construction that in the earlier days led to considerable losses. In fact, on every side, both in this country and abroad, the influence of the amateur radio experimenter has been felt, and that this work will continue is a foregone conclusion, for he is justifiably proud of his efforts.

Television

A new line of research which is appealing to the amateur is that connected with the progress of television.

I believe the same story will be told here as has been with regard to ordinary radio—he will help, and indeed is already helping, to popularise and create interest in this new phase of radio science. What has been done to serve the ear will be executed in a similar way to serve the eye.

OTHER RECENT DEVELOPMENTS

Although space is limited, no article of this nature would be complete without a reference to one or two important developments of quite recent date.

Short-Wave Work

First of all, short-wave work, while providing a wide field for experimenting, suffers from two rather unfortunate defects, namely, fading and "double reception."

The former is wrapped up largely in the movements of the heaviside layer, while the second is the outcome of the slightly differing times of arrival of the ground ray and reflected ray of the receiving station.

A good deal of attention has, therefore, been turned to the ultra short waves (about 10 metres and below), and although on these waves the two points just mentioned above appear to be eliminated the range over which signals can be received is limited by the "optical path" of the waves. That is to say, that unless the transmitting station is within sight of the receiving station nothing will be heard. Recent experiments, however, seem to indicate that this last statement is rather elastic and news has just come to hand that Marconi working on a wavelength of about ½ metre has established communication over a distance of no less than 168 miles. This seems to show that our theories on this subject may have to be revised in the same way that they were when amateurs carried out their short wave work.

The Stenode

Modern demands for selectivity have been met in a variety of ways, and one which has proved rather interesting is what is known as the stenode.

In essence a quartz crystal in conjunction with a tuned circuit makes the acceptor side of the receiver of razor edge selectivity. The higher frequencies are, therefore, reduced to a very low amplitude and reproduction would normally be poor. To counterbalance this, therefore, there is a post detector arrangement which restores the balance of the frequency amplification cut down so ruthlessly at the outset. Unfortunately, the scheme so far is not only expensive but is applicable only to wireless sets of the superheterodyne class. Following this we have the basic principle of the new type of receiver known as the "Autotone." Here is an alternative to the superheterodyne and band pass filter brought about by ultra selective tuning in conjunction with reaction and followed by tone correction in the L.F. amplifier to compensate for the inevitable attenuation of the higher audio frequencies. This type of receiver is quite stable in operation and uniform reaction is obtained by means of a special compensating device so that the set is controlled virtually by means of a single knob.

Modern Types of Valves

Finally, if any degree of finality can be suggested where radio is concerned, a word must be said in reference to the modern type of valves. For H.F. amplification the screen grid valve has almost replaced the old type of triode. With this scheme, stability is achieved with much greater amplification and it is no longer necessary to "hold the set down" with damping devices, while on the output side we have the modern pentode, which gives a larger output signal for quite a small input grid swing.

The combination of a screen-grid, detector and pentode represents up-to-date practice in modern receiver design and gives results exceeding in range, stability, quality and sensitivity the five or six valve set of a few years ago, this being coupled with a reduction of the controls to a bare two or three.

SERVICING

EDISON BELL RADIOGRAMOPHONE, A.C. AND D.C. BAND PASS RECEIVERS AND SUPER-HETERODYNE BATTERY MODELS

THE Edison Bell All-Electric 3- and 4-valve Band Pass instruments are supplied for A.C. or D.C. operation, and these are available in Table, Console and Radiogramophone models.

The following notes covering the installation and operation of these instruments are written round the A.C. models, and a special note appears if the procedure should be altered for D.C. instruments.

Fig. 1.—THE EDISON BELL RADIOGRAMOPHONE. ALL MAINS SUPER-HETERODYNE MODEL.

Installation and Operation

An aerial of the single-wire type—25 to 30 feet in length—is recommended, and it should not be longer than this in most cases, or selectivity will be impaired; the usual earth connection is of course necessary.

Quite good results can be obtained from an indoor or the mains aerial, but of course the range is greatly restricted; an outside or indoor aerial should be connected to the socket provided for this purpose, and when it is desired to make use of the mains aerial the plug situated between aerial and earth sockets should be inserted in the former.

Inserting the Valves

On removing the back of cabinet the chassis will be seen as illustrated, and the various valves, together with the "regulator" lamp in the case of D.C. models, which are numbered, should be inserted in their respective positions as shown. Valve replacements are dealt with later under "General Notes."

Adapting the Receiver to the Mains Voltage

Before making a connection to the mains, the cover plate should be removed and the fuse plug inserted in the pair of sockets applicable to the voltage of the electric supply mains. The ranges covered are 90—110 and 200—250 volts, 40—60 cycles: a special instrument is necessary for 25 cycles. The D.C. ranges are 190—215 and 215—260 volts. The motor fitted to the D.C. radiogramophone must also be set according to the voltage of supply, and this is accomplished by inserting the right-hand screw, which has an insulated head in socket, marked with nearest voltage, on the bakelite panel adjacent to the motor.

Replace cover-plate and, in the case of a D.C. model, the back of cabinet to avoid contact with live metal parts, when the instrument is ready for use.

Switching On

After connecting instrument to the mains, the switch on the left hand side of the cabinet in the case of receivers, and on the left hand side of motor board of the radiogramophone, should be put to the "On" position to bring the instrument into operation.

The switch on the right hand side of cabinet should then be set for "radio" and the switch knob on the left of front of cabinet turned until a coloured light appears in the left hand escutcheon, bringing a medium wave range of 250—550 metres into operation.

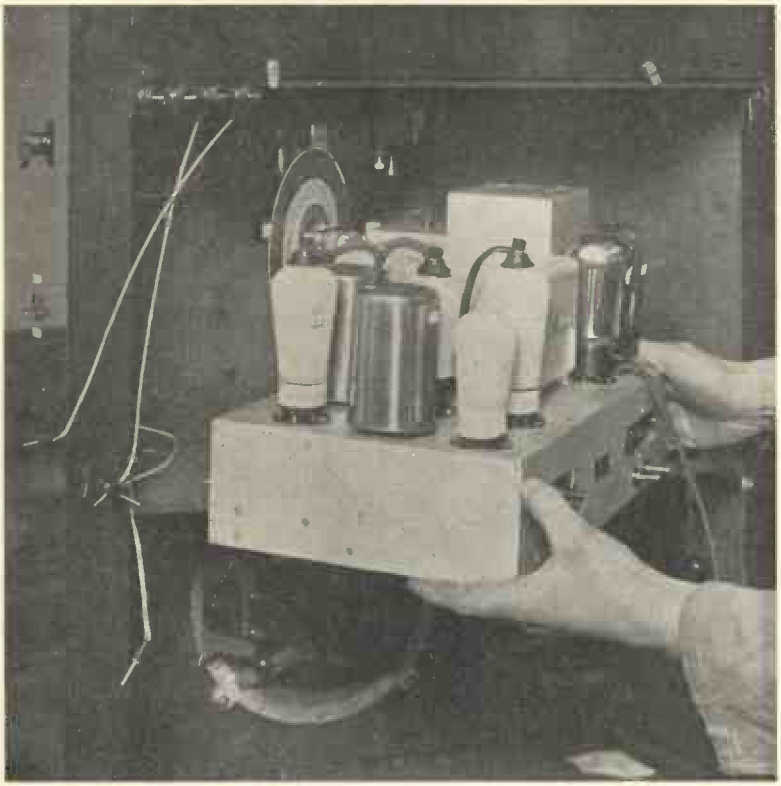


Fig. 2.—Withdrawing the Chassis of the Edison Bell All Mains Super-Heterodyne Radiogramophone.

Tuning

By this time the valves will have had time to heat up, and the central main tuning knob should be rotated until the name of the local station appears in the escutcheon. The right hand knob, which is attached to the volume control, should then be turned until the station is heard at medium strength; if no results are obtained at this point with the use of a D.C. instrument, and the (+) mains plug at the back of cabinet coincides with the (+) pin, then the plug at the other end of mains lead should be reversed in the socket to which it is connected; a white dot on side of plug indicates the (+) connection, and the position should be noted for future reference.

Setting the Trimming Condenser

The trimming condenser, which will be found at the back of chassis and in the D.C. model at side of cabinet above "gramo - radio" switch, should now be adjusted to a point where the most volume is obtained. It is essential for this "trimmer" to be accurately set, as otherwise distant station reception will not be satisfactory.

To ensure that this has been carried out it is as well to repeat the above procedure on a distant station; once the best setting has been found the adjusting knob can be locked in position by the small nut provided, and no further adjustment is necessary unless alterations are made to the aerial-earth system.

The Gramophone Side

When it is desired to use the receiver for the electrical reproduction of gramophone records, the switch on the right side of cabinet should be set to " gramo " and a pick-up, with its own volume control connected to the sockets adjacent to the aerial-earth connections: the radio volume control must be put to the minimum position. It is necessary to disconnect pick-up when radio reception is taking place.

A pick-up is, of course, already fitted to the Radiogramophone models, together with an electric turntable. To put the turntable into operation the automatic stop arm should be moved towards the pick-up arm; the Stop is fully automatic, and is so arranged that the motor automatically stops at the end of any type of record provided with a run-in line.

The gramophone volume control is situated just above the "Radio-Gramo" switch on side of cabinet. An additional loud speaker can be utilised with all models, and this should be connected to the " Ex.L.S." sockets.

CIRCUIT DIAGRAMS AND DESCRIPTIONS

A.C. Band Pass Three

As the name of this instrument implies, a band pass selector is used in the aerial circuit, and from Fig. 9 it will be noticed that a pre-set condenser precedes this, enabling the aerial capacity to be adjusted to conform with the ganging. A Multi-Mu Screened Grid valve is used in the H.F. stage and this is coupled to the detector by the tuned anode method. Reaction is arranged by means of the two parallel wires, one being connected to the grid of the S.G. valve and the other to the plate of the detector, the amount of feed back being controlled by the volume control potentiometer, which is the bias resistance in the cathode lead of the S.G. valve.

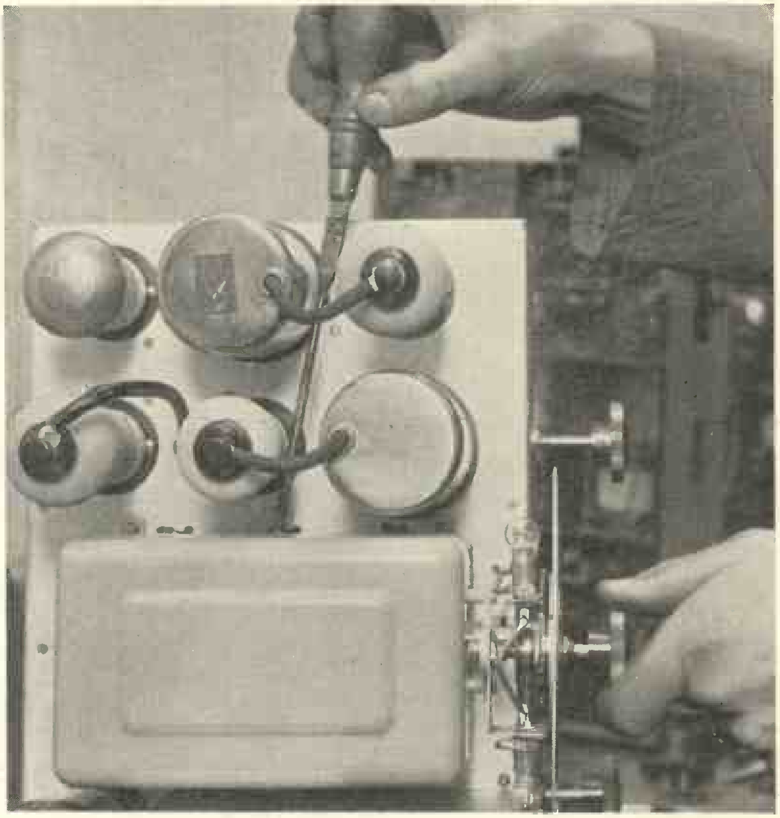


Fig. 3.—Adjusting the Trimming Condensers of the All Mains Super-Heterodyne Radiogramophone.

Grid Bias and Corrector Circuits

The A.C. pentode used in the output is transformer-coupled, and the bias for this stage is obtained from the drop in voltage across the loud-speaker field winding situated in the negative H.T. lead. A corrector circuit consisting of a ·01 mf. condenser and 15,000 ohm resistance is arranged across the loud speaker transformer. This transformer has a step down ratio of 30—1 and feeds into a speech coil having an impedance of 8 ohms.

In the case of the sockets for connecting an external speaker these are wired across the primary of the speaker transformer, which acts as a choke, and a 2 mfd. condenser is inserted in one lead.

The "Gramo-Radio" switch controls the bias on the detector valve, which is applied by means of a cathode resistance, shorting this out in the "radio" position. The filament supply is earthed through a centre tapped resistance, and all valves are in parallel in accordance with the usual custom in A.C. instruments.

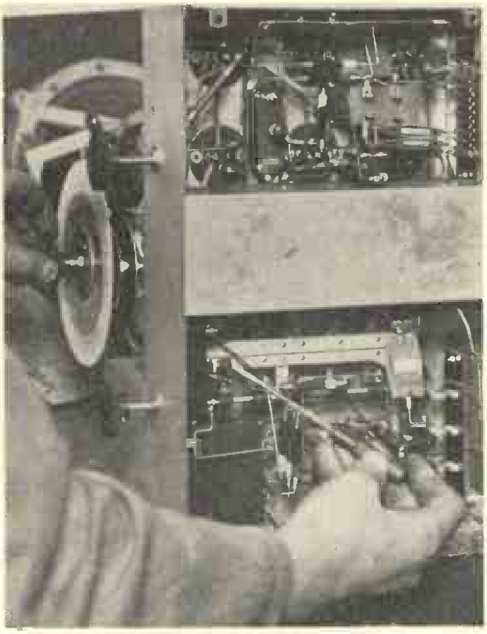


Fig. 4.—Adjusting the Padding Condenser. (All Mains Super-Het.)

Why Anode Feed Resistances are Included

In the H.T. supply anode feed resistances are included in each circuit for voltage dropping and de-coupling to prevent instability. The screening grid of the S.G. valve is fed from the junction of the 25,000 and 40,000 ohms resistances which form a potential divider across the H.T. supply to this valve.

A.C. Band Pass Four

Examination of Fig. 11 shows the use of two screened grid valves in the H.F. stages, and the volume control potentiometer forms part of the potential divider feeding the Screening Grids of these two valves.

How Sensitivity is Improved

To improve sensitivity a reaction effect is produced by means of a tag attached to the moving arm of the potentiometer, which alters its position relative to a thick copper wire connected to the anode of the detector valve: this wire is covered for part of its length by an earthed screen which is insulated from same. A piece of insulated flex connected to the aerial side of the first Band Pass Coil is passed through two holes in the tag referred to above; the wire is insulated from the tag and this completes the arrangement.

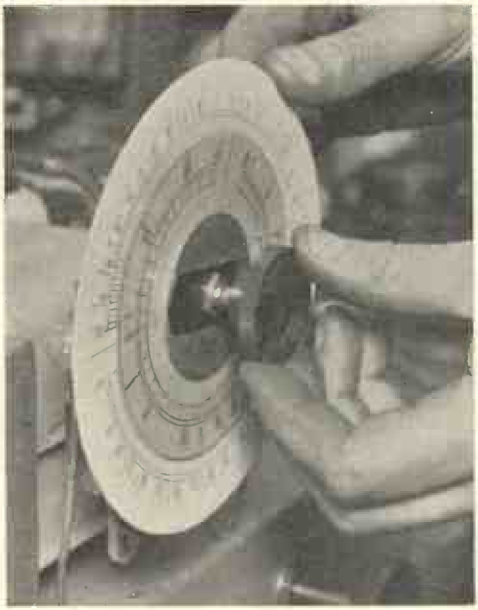


Fig. 5.—Method of Adjusting the Dial Readings after Trimming.

A tuned grid system couples the two H.F. valves and a choke arrangement is used between the H.F. and detector stages.

The remainder of the circuit is covered by the description of the 3-valve diagram.

D.C. Band Pass Three (Fig. 15)

This instrument uses the latest D.C. indirectly heated

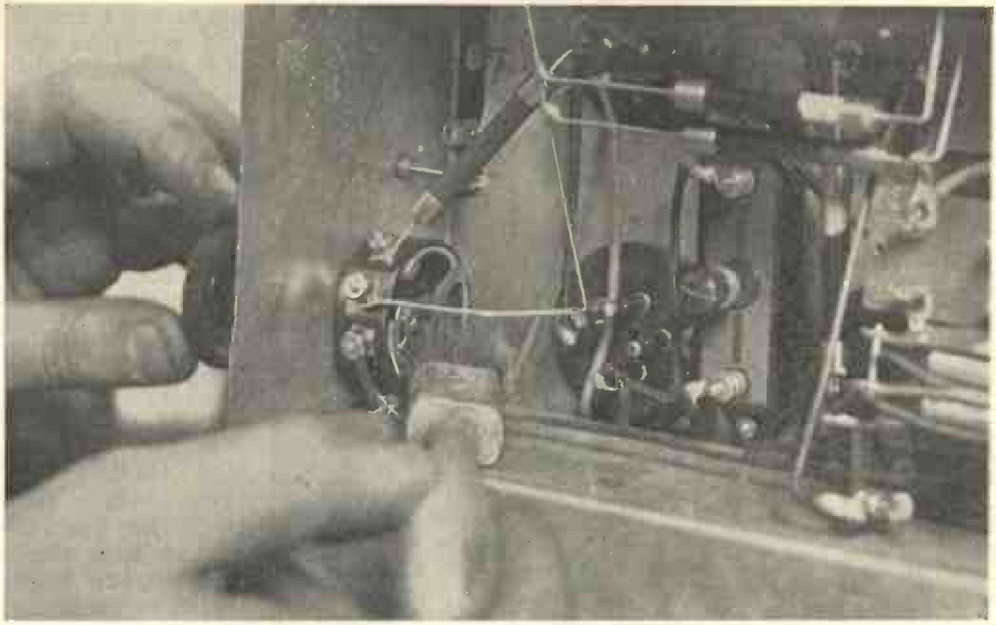


Fig. 6.—This shows How the Potentiometer can be Cleaned by Means of a Stiff Brush.

valves with 16-volt 0·25 amp. filaments which are arranged in series. The two pilot lamps used for lighting up the escutcheons on long and short waves are included in this circuit, together with a regulator or barratter lamp to safeguard the filaments against overload.

Apart from this, the circuit is on the same lines as the A.C. instrument, the only other slight differences being that a permanent magnet moving coil speaker is used in place of the field-excited type and a larger mains choke is used to make up for the absence of the field in the smoothing circuit. In the D.C. instruments it will be noticed that cathode resistances are used in every case for biasing.

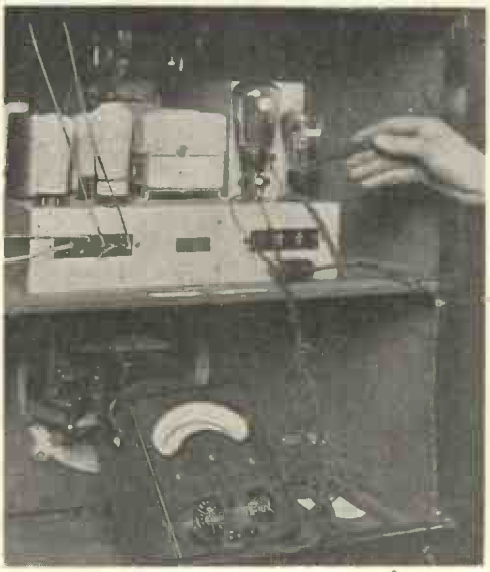


Fig. 7.—Testing the Valves.

D.C. Band Pass Four (Fig. 16)

The descriptions above of the 4-valve A.C. and 3-valve D.C. circuit arrangements cover all points in connection with the circuit adopted in this instrument.

FAULT TRACING AND REMEDYING

The following service notes cover in a comprehensive manner the faults met with in practice, the cause, and how to overcome them.

Complete Absence of Results

After having made sure that current is available at the lamp socket or plug point to which the instrument is connected, the fuse plug should be examined and the fuse renewed if necessary.

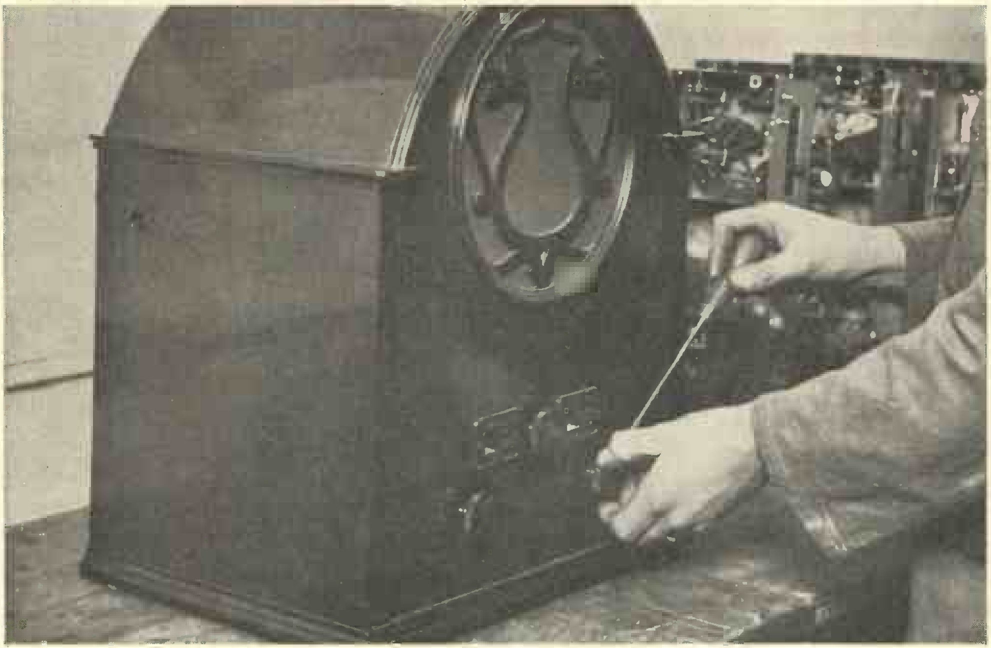


Fig. 8.—Removing the Control Knobs of the Edison Bell Band Pass Four Receiver.
This is done prior to withdrawing the chassis from the cabinet.

The fact that the pilot lamps behind the escutcheon are alight will serve as an indication that the mains are connected with instrument. In the event of a fuse continually blowing, there may be an internal short in one of the valves or a condenser broken down, and tests should be made accordingly.

Testing Emission of Valves

If the trouble does not lie in this direction, it is as well next to test the emission of the valves with the aid of a milliammeter and a valve-holder adaptor with split anode connection ; the various valves should draw current approximately as follows :—

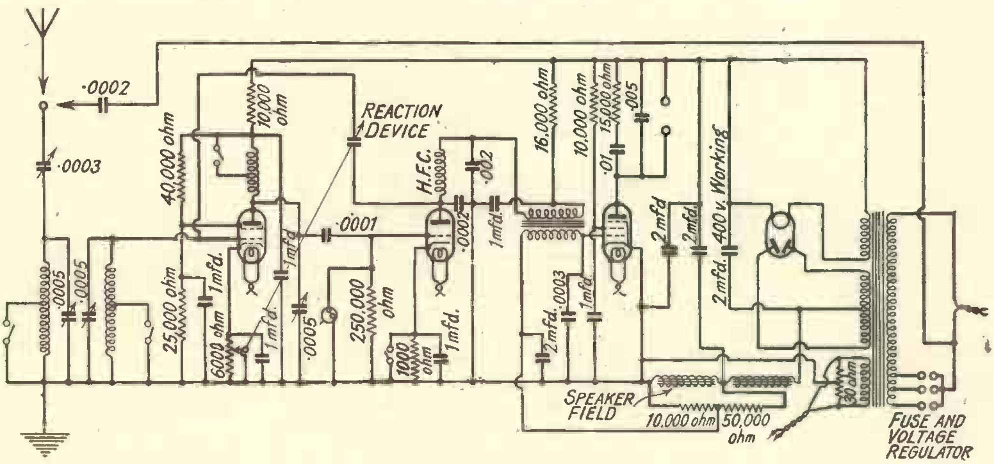


Fig. 9.—Circuit Diagram of A.C. Band Pass Three Receiver.

M.P.T.4	35 ma.
354V.	8 ,,
Mazda S.G.	5·5 ,,
M.M.4V.	5 ,,
D.P.T.	28 ,,
D.H.	5 ,,
D.S.B.	2 ,,

If no reading is obtained with any particular valve, it will in most cases be due to a dis in the filament and it will have to be replaced.

In the case of A.C. instruments, if no reading is obtained with any valve, then most probably the rectifying valve needs replacing.

With D.C. models, as the pilot lamps are switched in series with the filaments of the valves, care must be taken to see that they are screwed well home in the holders and should, in company with the regulator lamp, be tested for open circuit. The switch contacts should also be inspected to ensure that they are making properly.

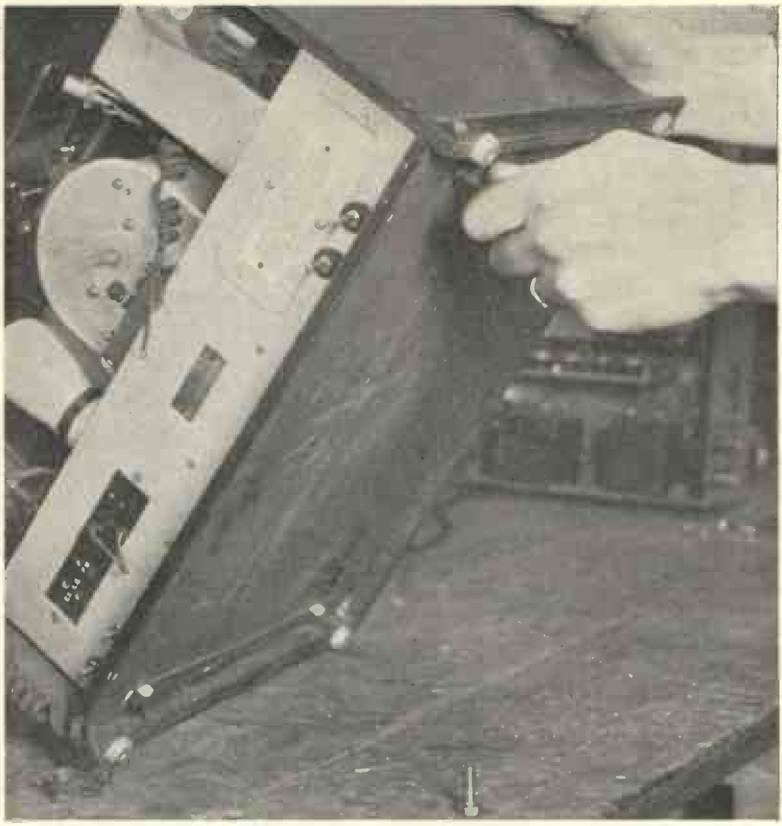


Fig. 10.—Removing the Chassis Bolt from Underneath the Band Pass Four Receiver.

Continuity Tests

If results are still not forthcoming, H.F. and mains chokes, loud speaker field wind-

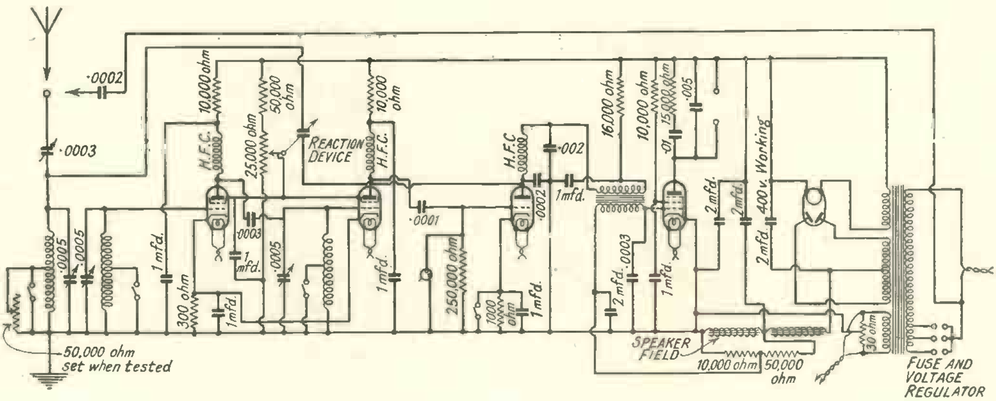


Fig. 11.—Circuit Diagram of A.C. Band Pass Four Receiver.

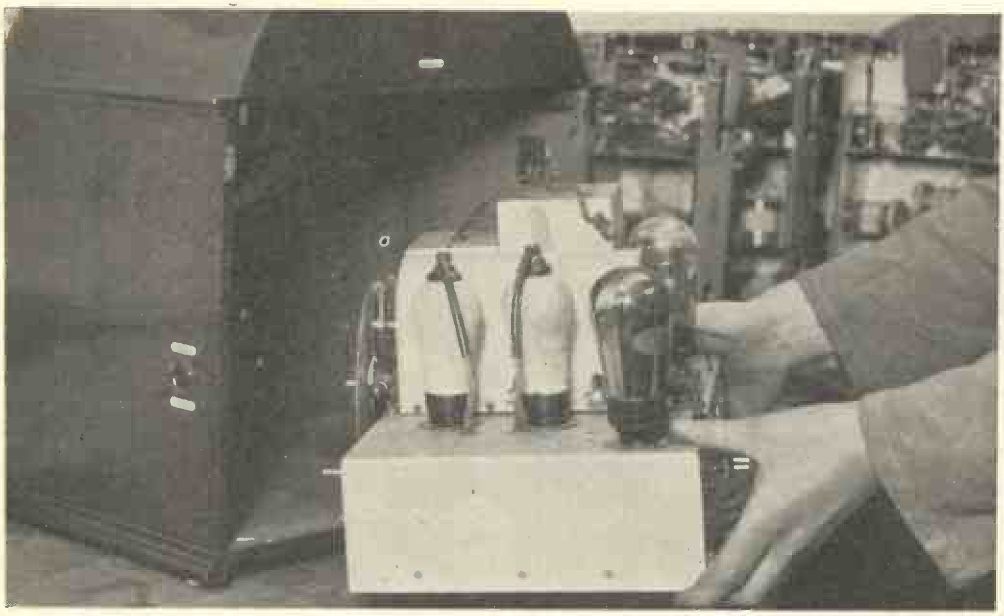


Fig. 12.—Showing How the Chassis can be Withdrawn. (Band Pass Four Model.)

ing, speech coil, mains and L.F. transformers should be tested for continuity, when the cause of the trouble should be apparent.

Removing Chassis from Cabinet

If it is necessary to remove chassis from cabinet the following procedure should be adopted: Loosen grub screws in tuning knobs and withdraw these from their respective spindles; disconnect all plugs and leads, including two sets of leads to speaker. Remove nuts from bolts holding chassis down to shelf on base of cabinet when chassis can be withdrawn.

Loss of Volume

This can be due to a variety of causes, but one of the most common is inaccurate adjustment of the trimming condenser; this should be readjusted, as the locking nut may have worked loose and the capacity have altered, throwing the gang condenser out of adjustment. The aerial-earth system may have altered in capacity, and this also would necessitate a fresh adjustment of the trimming condenser; aerial and earth leads should be carefully examined for a break, etc.

Fig. 13.—Tightening up the Baffle Board.

Switch contacts become dirty or tarnished sometimes, setting up a high resistance which would lead to a reduction of volume; these should be inspected and cleaned if necessary. If a resistance test set is available this can be brought into use for running over the various contacts.

Alteration of valve

Fig. 14.—ADJUSTING THE TRIMMING CONDENSERS OF THE BAND PASS FOUR RECEIVER.

Tune in to a local station and adjust the trimmer until the most volume is obtained. Now tune in a distant station, and, if necessary, readjust the trimmer. Then lock the adjusting nut in position.

characteristics is another cause, and tests should be made as suggested in the previous section.

What to Do when no Reaction can be Obtained

If no reaction effect is obtained when the volume control potentiometer is moved towards the maximum position in the case of the 3-valve instrument, the parallel wires connected to the S.G. Grid and Detector anode should be adjusted to bring them closer together, care being taken to see that they are not shorting. With the 4-valve range the relative positions of the end of the thick copper wire attached to the anode of the detector valve and the tag on arm of potentiometer should be altered correspondingly. The insulated wire passed through the tag should be inspected to ensure that this has not come out of position and also is not shorting to tag.

The adjustment of the volume control potentiometer should be inspected to ensure that this is making continuous contact with resistance element.

Poor Quality

This can usually be traced to a bad valve, as no cases have been experienced of feed or grid bias resistances breaking down.

Echo Effect in Loud Speaker

Where an echo effect is heard in the reproduction on small volume this is usually due to the speech coil of loud speaker having become slightly out of centre ; buzzing on certain notes is invariably caused by loose wires on the speech coil.

Loud speaker adjustments should be carried out by the makers, as special jigs are employed, without which it is difficult to centralise speech coil to avoid rubbing owing to smallness of gap in magnet.

Unsatisfactory or No Results on Gramophone Side

If no results are obtained this is usually due either to the " Gramo-Radio " switch not making good contact, a break in the pick-up winding, or the moving arm of the potentiometer volume control not making contact with the resistance element, and these items should be tested or inspected accordingly.

Distortion or Loss of Volume

Where there is distortion or loss of volume with an Edison Bell pick-up, this

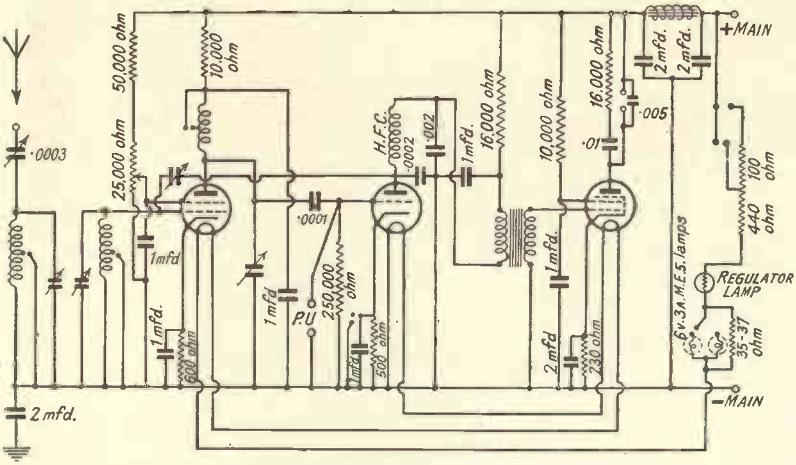


Fig. 15.—Circuit of D.C. Band Pass Three Receiver.

smoothing arrangements are so complete, but if there is any trouble in this respect it can usually be traced to a poor valve. With D.C. models, if the negative main is earthed and there is a slight hum, this can in most cases be cured by disconnecting earth wire to set.

can be usually traced to the armature being out of centre. To put this right the bakelite cap must be removed and the magnet pulled off the pole pieces, when the two grub screws, which will be seen locked in position by a small amount of wax, can be adjusted accordingly.

These should not be screwed up tight, as the rubber buffers which they control will damp the armature too much; the pressure should be just sufficient to centralise the armature when the pick-up is in use.

OPERATING NOTES

Hum

It is very unlikely that hum will be heard with an A.C. instrument, as the

Consumption from Mains

	Watts.
Band Pass Three Receivers . .	A.C.—32
,, ,, ,, ,, . .	D.C.—77
,, ,, ,, Radiogramophone	A.C.—50
,, ,, ,, ,,	D.C.—100
,, ,, Four ,,	A.C.—60
,, ,, ,, ,,	D.C.—110
,, ,, ,, Receivers . .	A.C.—40
,, ,, ,, ,, . .	D.C.—86

Mains Transformers, Chokes, etc.

The mains transformer is standard to all models, and outputs are provided as follows:—

H.T. 350—0—350 volts. 60 milliamps.
L.T. 4 volts 5 amps.
Rectifier filament. 4 volts 2 amps.

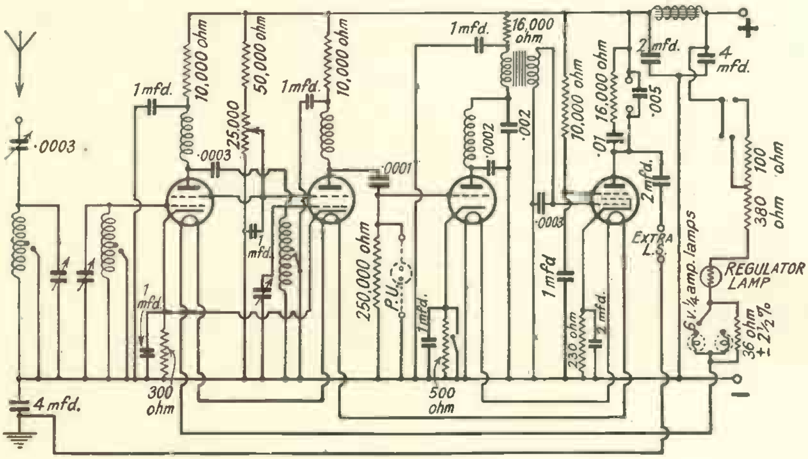


Fig. 16.—Circuit Diagram of D.C. Band Pass Four Receiver.

The smoothing choke has an inductance of 30 henries at 65 milliamps. D.C. resistance, 300 ohms. The field of the excited speaker has a resistance of 1,200 ohms and will carry 50—60 milliamps.

Pilot Lamps

These are of the 6-volt 0·2

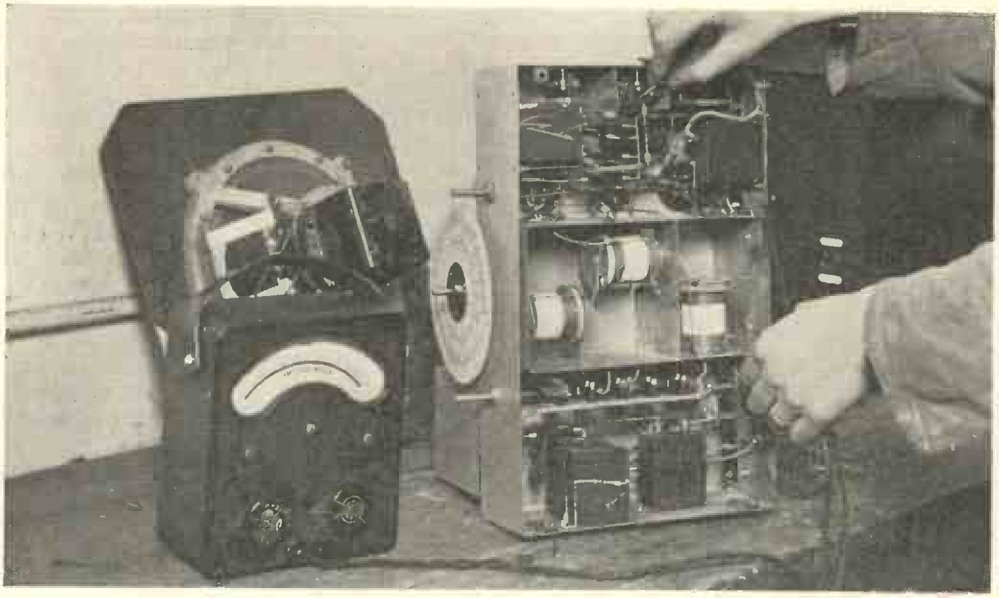


Fig. 17.—Testing Voltages on the Band Pass Four Receiver.

amp. type, and it is recommended that replacements be of the same rating. Lamps of a lower rating will not last any length of time.

Valves

The following valves or their equivalents should be used for replacement in the various positions shown.

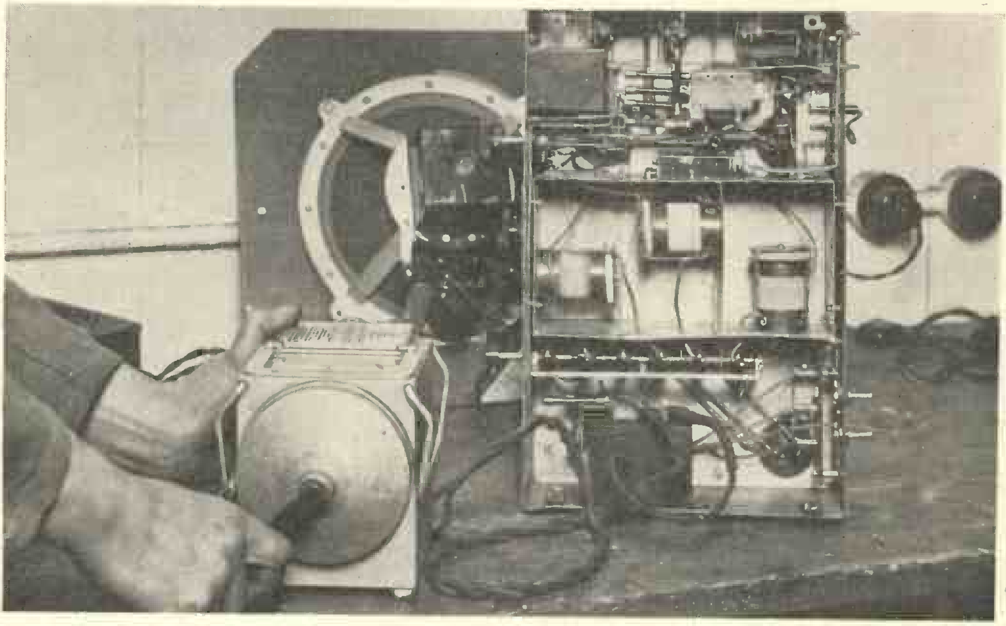


Fig. 18.—Testing Condenser Insulation.

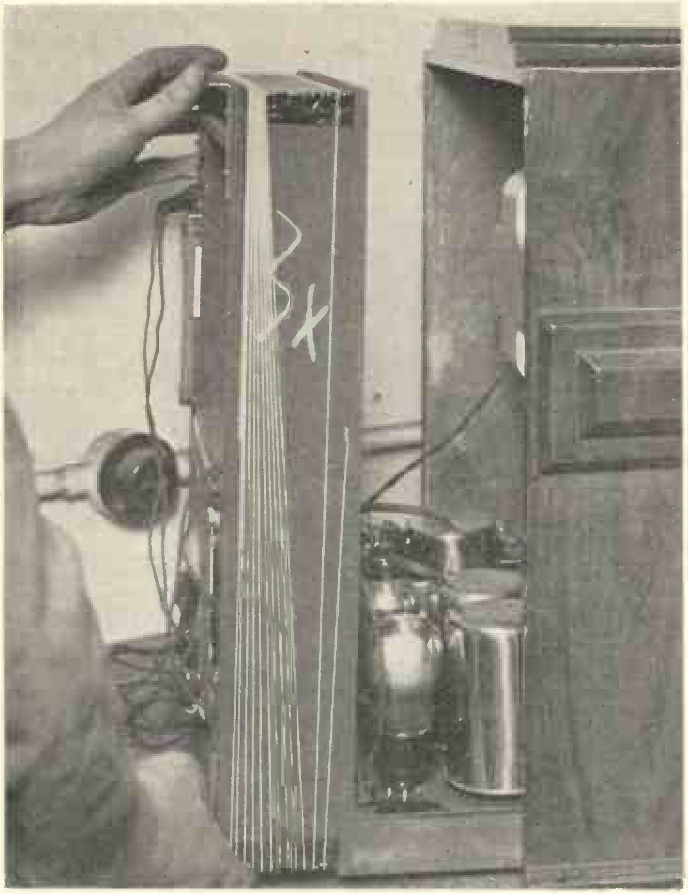


Fig. 19.—Removing the Chassis of the Battery Superheterodyne Receiver.

Note the frame aerial windings specially arranged for ganging with the coils.

A.C. Instruments

	Band Pass 3.	Band Pass 4.
H.F. Stages.	Mullard M.M.4V.	Mazda AC/SG.
Detector.	,, 354V.	Mullard 354V.
Output.	Osram M.P.T.4.	Osram M.P.T.4
Rectifier.	,, U.10.	,, U.12.

D.C. Instruments

	Band Pass 3.	Band Pass 4.
H.F. Stages.	Osram D.S.B.	Osram D.S.B.
Detector.	,, D.H.	,, D.H.
Output.	,, D.P.T.	,, D.P.T.
Regulator Lamp,	Philips 1920.	Philips 1920.

BATTERY MODEL SUPERHETERODYNE RECEIVER

Installation and Operation

An aerial-earth system is not necessary, and no provision is made for its use with this instrument as a frame aerial is incorporated.

The Battery Leads

After inserting the various valves in their respective valve holders, as indicated, the battery leads can be separated, and these will be seen to be marked or distinguished as follows :—

(*a*) Red and Black Spade Tags.
(*b*) G.B. +, G.B. − 1, and G.B. − 2.
(*c*) H.T. −, H.T. +, H.T. + 2, and H.T. + 3.

The leads shown under (*a*) are for connection to the 2-volt L.T. accumulator, which is housed in the compartment at the top left of set.

Connecting up the Batteries

The H.T. battery can now be placed in position in the bottom compartment: it should be kept over to the left with the negative (−) socket in the bottom left hand corner. In the remaining space to the right of the H.T. battery the grid bias battery is housed with negative (−) to the top. The leads under (*b*) and (*c*) should be connected to the grid bias and H.T. batteries as follows :—

Grid Battery

Insert G.B. (+) Red Plug in bottom (+) socket.

Insert G.B. (− 1) Black Plug in 1½-volts negative (−) (adjacent socket).

Insert G.B. (− 2) Black Plug in 3-volts negative (next socket).

H.T. Battery

Insert H.T. (−) Black Plug in bottom left hand socket.

Insert H.T. (+) Red Plug in the 27-volt socket.

Insert H.T. (+ 2) Red Plug in the 72-volt socket.

Insert H.T. (+ 3) Red Plug in the 108-volt socket.

The set is now ready for use, and the control knobs can be examined: the knob on the left controls the wave range and "On-Off" switch, this bringing the range of 250—660 metres into action when turned to the left and a tuning range of 1,000—2,000 metres when moved to the right.

When the switch is in the centre position all batteries are disconnected.

The knob on the right is attached to the volume control and the centre knob of the three is the main tuning control, this being fitted with a smaller knob for trimming or fine tuning.

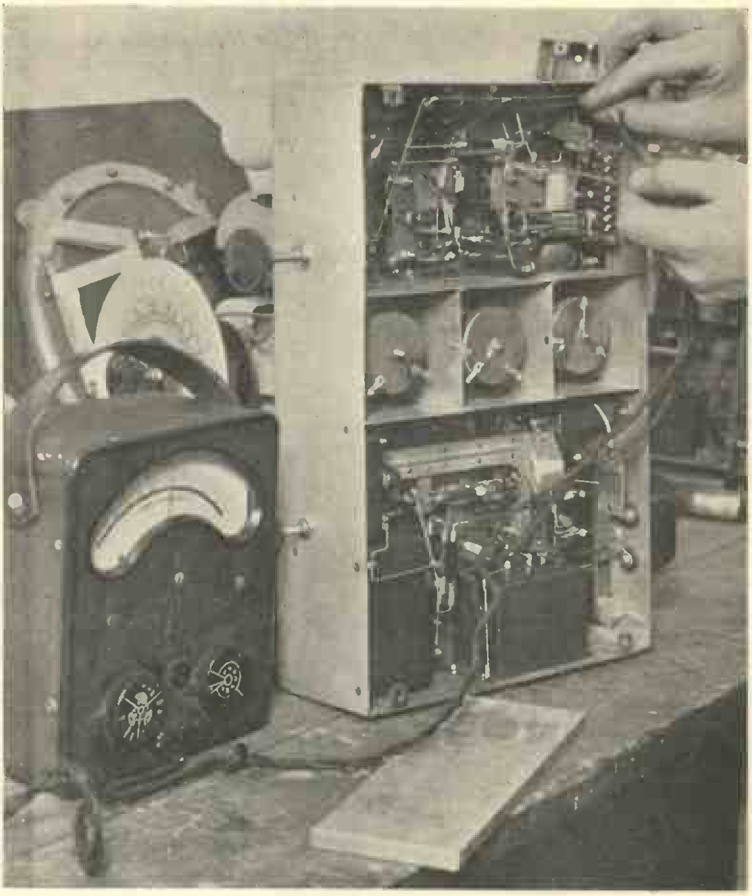


Fig. 20.—Making a Continuity Test.

The H.F. and mains chokes, loud speaker field windings, speech coil, mains and L.F. transformers should be tested for continuity.

Tuning is carried out in the usual manner, and this is greatly simplified by the wavelength calibration on the dial.

A turntable is fitted to facilitate rotation of the cabinet, thus enabling the frame aerial to be brought into line with the required station.

Circuit Diagram and Description

Fig. 22 shows that five valves are used, the first a double grid type combining the function of first detector and oscillator; two screened grid valves are used in the intermediate amplifier, a triode as second detector and a low-consumption pentode in the output.

The frame aerial and oscillator coil are tuned by the two gang condenser, the trimming condenser being in parallel with the aerial section.

When the switch is set for medium waves the two sections of the frame aerial are arranged in parallel and in the long wave position in series; the lower portions of the oscillator coils, it will be seen, are shorted out on medium waves.

Band pass coils are used in the intermediate amplifier, and volume is controlled by a rheostat common to the filament circuit of the two valves.

Nothing else in the circuit seems to call

This article on "Servicing Edison Bell Receivers" is continued in Part 8. Ready November 4th. Order your copy to-day.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

THE PENTODE VALVE

By S. R. Mullard, M.I.E.E.

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

COIL WINDING

"EELEX" SHORT WAVE CONVERTER

Etc., Etc.

1/-

Part 8

IN ABOUT 24 WEEKLY PARTS

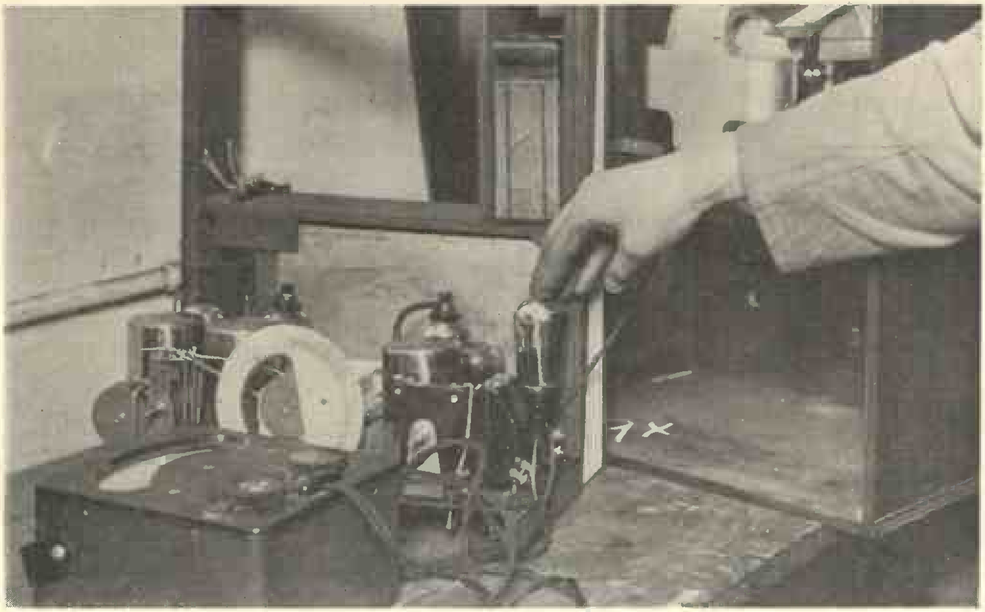


Fig. 21.—Testing Valve Emission.

This is done with a milliammeter and a valve holder adaptor with split anode connection. This illustration also shows the valve being rocked to ensure good contact.

for any special comment except perhaps the ·004 mfd. condenser across the pentode valve which, in company with the ·01 mfd. condenser shown, acts as a tone corrector.

Service Notes

Beyond the failure of batteries or valves there is very little to go wrong with this instrument, and, in fact, the very few cases where service has been necessary a valve which has lost its characteristics or an exhausted battery has proved to be the source of trouble.

Removing Instrument Chassis

If it is necessary to remove the instrument chassis at any time, all batteries should be firstly disconnected and removed. The two leads on the extreme left and the three on the right should then be disconnected from the loud speaker and frame aerial respectively. Next remove the screws from brackets holding the frame aerial in position, when it will be found that this can be withdrawn from cabinet. Remove screws passing through small brackets affixed to chassis, and after removing tuning knobs the chassis can be withdrawn.

General

The following particulars are given as a guide to the types of accessories

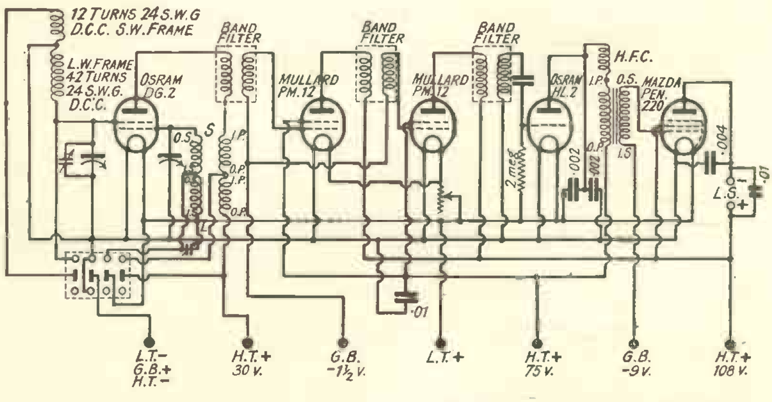


Fig. 22.—Circuit Diagram of Battery Super-Heterodyne Receiver.

Fig. 23.—Testing the High Tension Battery on Load.

which should be utilised for replacement :—

Drydex 108-volt H.T. Battery (Blue Triangle H.1018).

Drydex 9-volt Grid Battery (Red Triangle H.1001).

Exide Jelcel 2-volt 27 amp. Accumulator, Type J.W.T.5.

Osram D.G.2 Valve or Mullard P.M.1 D.G. (Detector and Oscillator).

Mullard P.M.12 Valve (Intermediate Amplifier).

Marconi or Osram H.L.210 Valve (Second Detector).

Mazda Pen. 220-valve (Output).

Pilot Lamp, 4·5-volt 0·2 amp.

EDISON BELL ALL MAINS SUPER-HETERODYNE

A five-valve instrument for operation on A.C. mains 200–250 volts 40–60 cycles which is available as a table model receiver and in radio-gramophone form.

Installation and Operation

The particulars of the aerial-earth system given in the section dealing with the band pass models also apply in this instance ; provision is also made for the use of a mains aerial.

In setting up the instrument it will be noticed that the valves and screened coils are numbered to correspond with numbers appearing against each valve holder and care should be taken to see that these are inserted in the correct positions ; the various types of valves and their respective functions are shown under " Valve Replacements."

The leads attached to the screened coils are, of course, for connection to the terminals at the top of the adjacent screened-grid valves and a further lead nearby the other screened-grid valve should be connected in a like manner.

After the fuse plug has been inserted in the sockets applicable to the voltage of the mains supply available, as indicated in the section referred to above, tuning can be carried out in precisely the same manner as the band pass models with the exception that there is no " trimmer " condenser to adjust as a coupled aerial circuit is adopted.

The reproduction of gramophone records is dealt with fully under band pass models and the same remarks apply.

An additional loud speaker can also be used as suggested.

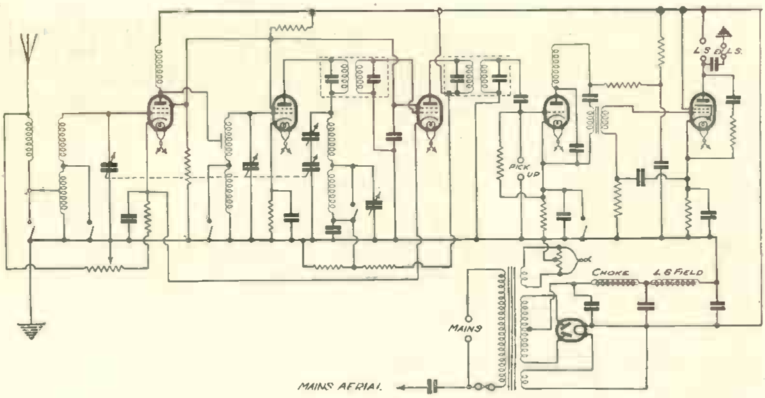


Fig. 24.—CIRCUIT DIAGRAM OF THE EDISON BELL ALL MAINS SUPER-HETERODYNE RECEIVER.

Description of Circuit

The circuit diagram of the Edison Bell All Mains Super-Heterodyne is shown in Fig. 24 and on examination it will be seen that an initial multi-mu H.F. stage is used followed by a screened-grid valve which acts as a combined first detector and oscillator. As stated above a coupled aerial circuit is utilised with a tuned grid arrangement between H.F. and first detector stages. A special link circuit is used consisting of a single ring of heavy gauge wire tightly coupled to the tuned grid coil this being connected to the anode of the H.F. valve.

These circuits together with the oscillator coils are tuned by a three-gang condenser and a small padding condenser is used in the oscillator section.

A multi-mu valve is used in the single intermediate stage and the couplings as shown are of the tuned band pass variety.

The volume control takes the form of a potentioneter which simultaneously adjusts the bias of the multi-mu valves used in the initial H.F. and intermediate stages, thus avoiding the possibility of overloading the first detector.

The second detector it will be seen is coupled to the corrected Pentode output valve by means of a resistance fed transformer.

When used as a pick-up amplifier the second detector is biased by means of a cathode resistance and the same method is adopted in the case of the output valve; in the latter case a de-coupling arrangement is also used.

The primary of the "loud speaker" transformer when connected to the L.S. terminals shown, it will be noticed, acts as a choke providing a high impedance input for an external speaker.

Service Notes

The servicing of Edison Bell apparatus is dealt with comprehensively in the previous pages and if the source of any trouble which might develop cannot be traced after the tests indicated have been carried out it is as well to take the matter up with the makers.

Valve Replacements

The following particulars are given as guide to the types of valves which should be used for replacement :—

Mazda A.C.S.G., First Detector, etc., Valve.
Mullard M.M.4V., Intermediate Valve.
Mullard M.M.4V., H.F. Valve.
Mullard 354V., Second Detector Valve (Metallised).
Mazda A.C. Pen, Pentode Out-put Valve.
Osram U.12, Rectifier Valve.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION VII—ELECTRIC FIELDS

As we shall see later, wireless waves consist of two varying fields of which the horizontal one is magnetic and the vertical one is electric. These two fields vary in step, when one grows the other grows, when one diminishes the other diminishes, and when one disappears the other disappears. This behaviour is different from that when an electric and a magnetic field exist near a conductor in which an alternating current is flowing, as then the two fields are not in step, and when one has a maximum the other is zero, *i.e.*, non-existent.

Speed of Wireless Waves

It is only when the two fields get into step that they leave the conductor producing them and travel in space with the incredible speed of 186,000 miles per second. This is equivalent to 669,600,000 miles per hour.

Since the wireless wave is a combination of these two fields, if we are to know something about it, we must make ourselves familiar with each field. We have already dealt with the magnetic field in Section V., and we shall deal now with the electric field, which is very similar to the magnetic one.

Electrons and Protons

Electrons and protons were created in pairs. If we can get hold of an isolated electron it means that there is somewhere a proton left unbalanced. We cannot have a negative charge without a corresponding positive charge. If electrons are to be in surplus on one body there must be a deficit on some other body.

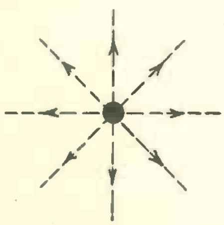


Fig. 1.— Distribution of Lines of Force of the Electric Field around an Isolated Proton.

Electrons attract Protons

An electron attracts a proton, and this attraction is manifested by a field between the two particles, a field which is somewhat similar to the magnetic field between two unlike poles, as the lines of force of the electric field, which are really lines of strain in the ether, are flowing from the proton to the electron.

A Three-dimensional Field

Let us represent an electron as a circle and a proton as a black dot. Then in Fig. 1 we have the distribution of the lines of force of the electric field around an isolated proton. Similarly in Fig. 2 we have the electric field around an isolated electron. These lines of force should be imagined as invisible lines of strain in the ether, spreading from the " surface " of the proton or terminating on the electron in *all directions*. It is a three-dimensional field. In Fig. 3 an electric field is shown between a proton and electron. In this case you should not forget that we are dealing with attraction. If you compare this electric field with a magnetic field existing between two unlike magnetic poles you will not fail to notice the similarity.

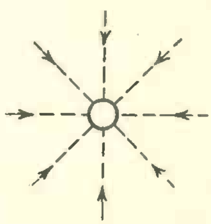


Fig. 2. — Distribution of Lines of Force of the Electric Field around an Isolated Electron.

How Electric Fields between Two Protons and Two Electrons Differ

In Fig. 4 is shown an electric field between two protons, and in Fig. 5 between two electrons. These two fields are identical except for the direction of the lines of force, which always begin on a proton and terminate on an electron. In this case we can recognise at a glance from the way the lines of force distribute themselves that we are dealing with repulsion.

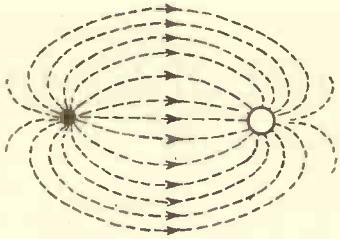


Fig. 3.—ELECTRIC FIELD BETWEEN A PROTON AND AN ELECTRON.

The intensity of the electric field grows with the number of lines of force per unit area taken at right angles to the field.

An Experiment with a Straw

If we investigate the space between two charged spherical conductors we shall find that the distribution of the electric field is the same as in the case of an electron and a proton. Such a field can be investigated and its distribution of lines of force mapped with the help of small straws pivoted on a fine point. In this case the straw will act in a manner similar to that of a small compass needle in the case of a magnetic field.

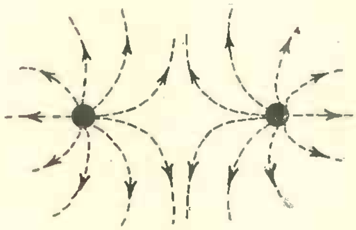


Fig. 4.—AN ELECTRIC FIELD BETWEEN TWO PROTONS.

Electric Field in the Case of Spherical Conductors

Figs. 6, 7 and 8 show the electric field in the case of spherical conductors isolated from earth and other electrified bodies. Again, it is easy to recognise when attraction and repulsion takes place.

As we shall see later, there is an electric field between the two sets of plates of a condenser when the latter is charged. The appearance of such a field is shown in Figs. 9 and 10.

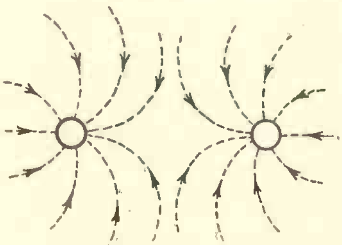


Fig. 5.—AN ELECTRIC FIELD BETWEEN TWO ELECTRONS.

Field produced by Electrostatic Induction

An interesting electric field is obtained when electro - static induction takes place, and this field is shown in Fig. 11.

A spherical conductor suspended in air near the earth surface will produce, when charged, a field such as shown in Fig. 12.

Field Round a Positively-charged Vertical Wire

A vertical wire charged, say, positively, will have an electric field all round it, and this field is shown in section in Fig. 13. It should be clearly understood that the real field around such a vertical wire is spherical in its shape and what we show on paper in the flat is only a section of it.

How an Electric Field gets detached from the Conductor

Let us consider now how it is possible for an electric field to get detached from the conductor. Let us imagine an isolated electron in space flying with some arbitrary speed. In the first place, since there is an electric field around it, as shown in Fig. 2, this electric field, which is a *strain in the ether*, will travel with the electron. In addition to this field there is also a magnetic field which is due to the stress in the ether caused by the moving electron. The lines of force of the magnetic field can be visualised as a sphere of stress around an electron and moving with it (Fig. 14). Should an electron for some reason or other change its direction, the electric field as well as the magnetic field will undergo a shift. This is clearly shown in the case of an electric field in Fig. 15. The disturbances in the old direction will not disappear all at once, and, combining into an electro-magnetic wave, will travel in space forming what we call a radiation.

Thus, a change of direction in the flight of an electron will produce an electro-magnetic wave in the ether. This is the cause of such radiations as heat, light, etc.

What happens when an Electron is suddenly stopped

Again, if an electron is suddenly stopped the strain and stress in the ether around it, *i.e.*, the electric and the magnetic field, will not stop, but will carry on as an electro-magnetic wave. Now, when such a combination of an electric and a magnetic field travels in space and comes close to a neutral conductor, *i.e.*, a conductor in which there is no movement of electrons, the electric field will react on the electric fields around the electrons in the atoms of the conductor, and by either attracting or repelling them will make them move.

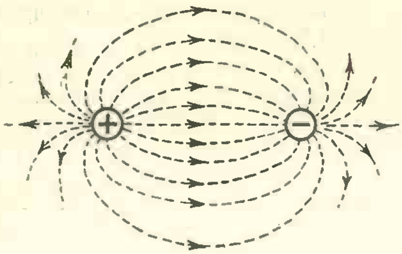


Fig. 6.—ELECTRIC FIELD IN THE CASE OF SPHERICAL CONDUCTORS ISOLATED FROM EARTH AND OTHER ELECTRIFIED BODIES.

This shows a positive and a negative conductor.

Similarly, when the magnetic portion of the electro-magnetic wave meets a closed conductor, such as a frame aerial, it will cut its turns at right angles and will induce currents in them. An ordinary outdoor or indoor aerial is therefore acted upon mainly by the electric field while the frame aerial is acted upon by the magnetic field.

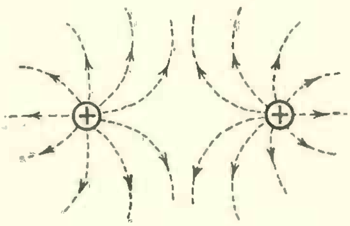


Fig. 7.—THIS SHOWS TWO POSITIVE CONDUCTORS.

An electric field establishes itself between an open aerial and the strip of earth below it as shown in Fig. 16.

Current in an Aerial

If the current in the aerial (in Fig. 16 we are dealing with a transmitting aerial) is an alternating one the electric field will also be an alternating one; it will start from zero, increase smoothly but quickly to a maximum, and then diminish to zero again. After that it will reverse its direction and will start growing again to a maximum only, once more to diminish to zero.

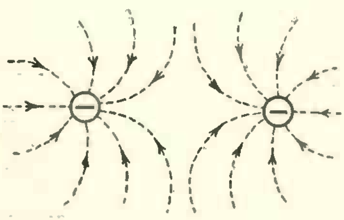


Fig. 8.—THIS SHOWS TWO NEGATIVE CONDUCTORS.

Electronic Tide of Varying Intensity

The reason for all this is the nature of the current flowing in the aerial. This rapidly oscillating current can be considered as an electronic tide of varying intensity, now flowing this way, now the opposite way. At the beginning of the cycle of events there are no electrons moving, and for this reason, since the aerial is neutral, there is no electric field between the aerial and the earth. Immediately after, a few electrons start to flow into the aerial and a few lines of force of the electric field will make their appearance in the space under consideration. As more and more electrons are flowing into the aerial under the influence of similarly growing E.M.F. applied to the aerial, more and more lines will establish themselves between the aerial and the earth, and so the field will grow to its maximum of lines of force.

The First Half-cycle

After the maximum is reached fewer electrons are flowing into the aerial, their number is gradually diminishing as the applied E.M.F. is dying away, and the number of lines of force will become scarcer and scarcer, till, when the electrons have ceased to flow altogether, all the lines of force will disappear. Half a cycle of events has taken place.

The Second Half-cycle

At the beginning of the second half-cycle the "tide" turns and electrons are being drawn away from the atoms of the aerial. Protons now become gradually more and more predominant in the

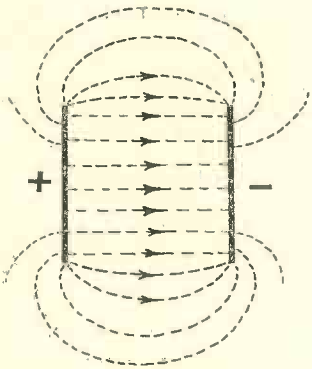


Fig. 9.—THIS SHOWS THE ELECTRIC FIELD BETWEEN THE TWO SETS OF PLATES OF A CONDENSER WHEN IT IS CHARGED.

aerial wire, and for this reason the direction of the electric field promptly reverses. The same gradual changes in the number of withdrawn electrons take place as in the first half-cycle, the flow of electrons from the aerial gradually grows to a maximum and then diminishes to zero, and the electric field will follow the same variations and grow and diminish in the reverse direction.

An Electro-magnetic Wave

Whatever the wavelength of transmission, at a distance equal to a quarter of the wavelength * from the aerial, the electric and the magnetic field, which within this quarter of the wavelength were out of step, are shaken into step and thus are formed into an electro-magnetic wave of an alternating nature.

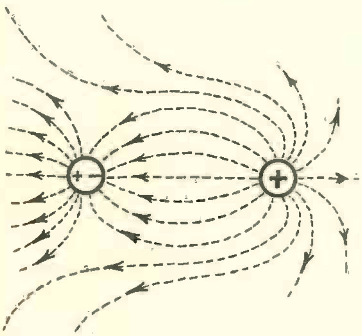


Fig. 11.—ELECTRIC FIELD OBTAINED WHEN ELECTRO-STATIC INDUCTION TAKES PLACE.

* If the wavelength is 300 metres, then a quarter of this is 75 metres away from the aerial, where the two fields combine.

The Travelling Electric Field

Now, when such a wave reaches a receiving aerial, the travelling electric field establishes itself between the aerial and earth as the plates of a condenser. More and more lines of force arrive from space till a maximum is reached, and after this the number of lines diminishes to zero. The lines of force of the electric field, during the next half-cycle, are arriving in the reverse direction and undergoing the same variations as before. When the field arrives in one direction it attracts the electrons in the atoms of the receiving aerial towards itself or repels them away from itself when arriving in the opposite direction (see the arrows in Fig. 16).

Thus, as the electric field is gradually increasing and diminishing in strength and changing in direction it will cause the electrons in the aerial to oscillate to and fro in exactly the same manner in which the electrons in the transmitting aerial were oscillating, provided both aerials are tuned to the same wavelength.

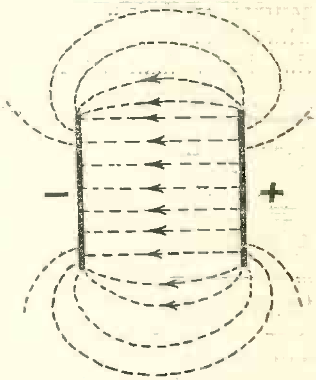


Fig. 10.—THIS ALSO SHOWS THE ELECTRIC FIELD BETWEEN THE TWO SETS OF PLATES OF A CONDENSER.

What Happens between Transmitting and Receiving Aerials

It is clear, therefore, that in the first place oscillating electrons in the transmitting aerial have sent a series of electrical fields into space combined with magnetic fields, and these electrical fields on reaching the receiving aerial have caused electrons in it to oscillate in the same way in which electrons were oscillating in the transmitting aerial.

The above explains roughly the broad idea of wireless communication, as since we are able to control the flow of electrons in a conductor at will, we can arrange for these electrons to move and to actuate various devices which will give prearranged signals.

Aerial Screening

It is clear that an electric field is capable of moving electrons in any conductor, be it a receiving aerial or not. Every time it moves electrons it dissipates some of its energy. For this reason, if the electric field encounters on its way to your receiving aerial a high hill containing conducting materials, a tall building with steel girders, a forest of tall trees, it will dissipate some of its energy in moving the electrons on the surface of these obstacles

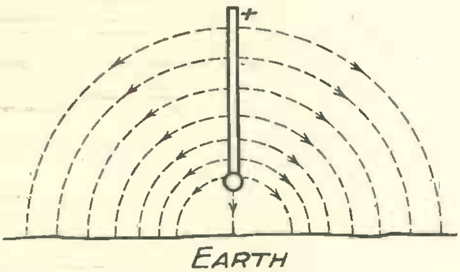


Fig. 13.—This shows the Electric Field all round a Vertical Wire charged positively.

and will arrive considerably weakened by the time it reaches your aerial. This means that your aerial is *screened* to some extent from the transmitting station.

How Height of Aerial Affects Reception

In order to receive the full benefit of the electric field your aerial should be as high as possible within economical limits and within the permitted length. Your earth connection should be efficient, and both the aerial wire and the earth wire should be of high conductivity (low resistance). In this way you will facilitate the work of the electrical field.

Why Lightning Discharges Affect an Aerial

Just as an electric field establishes itself between two charged conductors, or a charged conductor and earth, so an electric field will establish itself between two clouds carrying opposite charges or between a cloud and earth. Should the clouds carry large charges and come close to each other to break down the insulating properties of the air surrounding them, or be there moist air between the clouds, there will be an exchange of electrons from cloud to cloud, or from a cloud to earth, and we get what we call lightning. A lightning discharge, which consists of a large number of rapidly moving electrons, will cause an electromagnetic wave in the ether as if it were a gigantic broadcasting station.

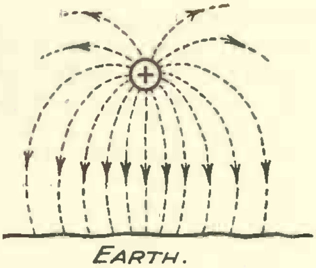


Fig. 12.—Electric Field produced when a Charged Spherical Conductor is suspended in Air near the Earth Surface.

The tremendous electric field of this wave arriving near your aerial will jerk the electrons in it in a most violent manner and there will be a heavy surge of electrons. This will cause loud crashes in the loudspeaker, and should this surge be too large and there is no provision made for dissipating the unwelcome energy with the help of a so-called lightning arrester, the surge of electrons may cause a large heating effect in the wires of the receiver and burn them out. Such atmospheric discharges are called *atmospherics* and sometimes statics.

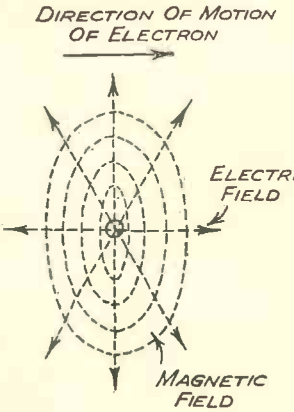


Fig. 14.—Diagram showing the Lines of Force visualised as a Sphere of Stress around an Electron and moving with it.

The electric field does not only play an important *rôle* in the case of the aerial, but is also of importance in the action of various components used within the receiver. Wherever it is present it reacts on the electrons within its reach and its influence must always be taken into consideration.

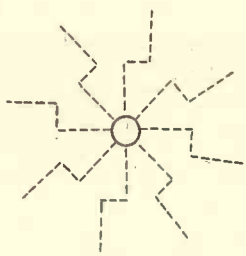


Fig. 15.—Showing how the Magnetic Field will undergo a Shift should an Electron for some reason or other change its direction.

Effect of Capacity

Whenever we have two charged conductors, whatever their shape, close together, we have capacity present and electric field established between the two conductors. This unavoidable capacity alters the nature of the alternating current flowing within the conductors, and must therefore be taken into consideration.

In the case of condensers, this capacity is regulated by the provision of convenient values, but in the case of such components as valves and coils, as well as transformers, there is no such regulation, as the conductors are spaced in a certain way for all sorts of reasons, and the capacity either between valve electrodes or between turns of a coil is an unavoidable evil that must be put up with and counteracted as much as possible.

Electric Field between Grid and Anode of a Valve

Fig. 17 shows the existence of an electric field between the grid and the anode of a valve. It owes its existence there owing to opposite charges or unequal charges on these two electrodes. The effect is the same as if a small condenser were placed across the grid and the plate. When you are fully acquainted with the action of a condenser you will appreciate what this means.

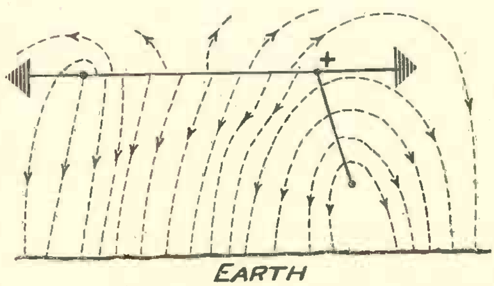


Fig. 16.—Showing how an Electric Field establishes itself between an open Aerial and the Strip of Earth below it.

Electro-static Field between Conductors of a Coil

In Fig. 18 an electrostatic field is shown between the conductors (insulated from each other) of a multilayer coil.

Here, again, we have a state of affairs equivalent to placing a condenser across each pair of turns of the coil. And the coil, which is a device for providing inductance, thus also provides capacity.

If we have an alternating current flowing in a conductor and reversing its direction with high frequency, say, a million times a second, and this conductor is placed near another conductor in which currents are flowing at much lower frequency, it is clear that a high frequency alternating electric field will be established between the two conductors, and the conductor carrying a low frequency current will have a high frequency current induced in it by the high frequency alternating field.

Why Components are Screened

In order to avoid this, in a wireless receiver, a condition which means that there will be a good deal of distortion of the intended signal introduced, the high frequency component is screened from the low frequency component with the help of a metallic screen. This is especially necessary in the case of a screened grid valve which forms part of the high frequency amplifying circuit.

How Screening is carried out

In order to appreciate how this screening is carried out it is necessary to consider the following. We already know that in order to isolate a magnetic field it is sufficient to surround the source of magnetism by an *iron* shield so that the lines of force distribute themselves within the iron shield instead of spreading in an undesired direction and affecting another circuit.

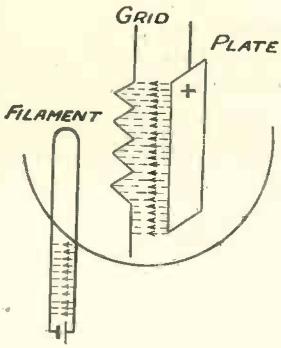


Fig. 17.—This shows the existence of an Electric Field between the Grid and the Anode of a Valve.

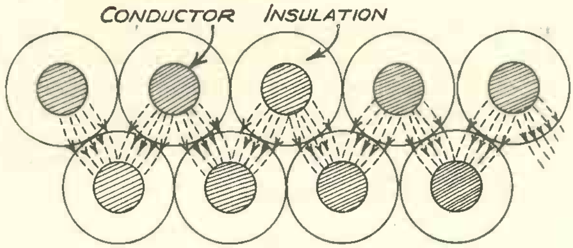


Fig. 18.—This shows an Electro Static Field between the Conductors (insulated from each other) of a Multilayer Coil.

Screening an Electric Field

In the case of an electric field a similar method is used, only in this case the screening pot or case can be made of *any metal* of high conductivity. In Fig. 19 this method is shown. A screening pot is placed around the component that is necessary to shield.

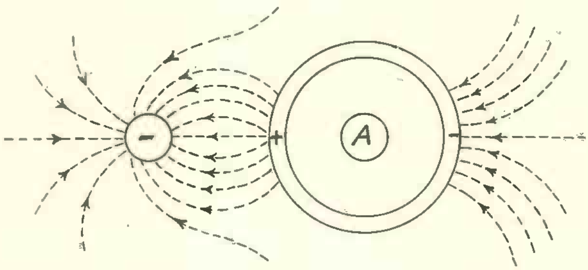


Fig. 19.—This shows the Effect of a Screening Pot placed around a Component that it is necessary to shield.

As can be seen, electrostatic induction takes place and the electric field distributes itself, as shown, without affecting the space inside the pot. Should the component A be earthed, the screening pot is also connected to earth. It is advisable to enclose within metal sheathing all wires carrying high frequency currents so as to avoid their affecting other circuits.

The next section will deal with the theory of condensers.

QUESTIONS AND ANSWERS

At what Speed do Wireless Waves travel ?

They travel at 186,000 miles per second, or 669,660,000 miles per hour—roughly, 700,000,000 miles an hour.

What is the Scientific Description of Wireless Waves ?

They are called by scientists electro-magnetic waves because it has been found that a wireless wave is associated with an electric field and a magnetic field.

In Wireless Reception which of these effects is the more Important ?

Both effects are equally important, *i.e.*, an outdoor aerial is acted upon chiefly by an electric field whereas a frame aerial responds chiefly to magnetic fields. In each case, however, both fields are affected.

What is the principle involved in generating Wireless Waves ?

In its simplest form it may be said that electro-magnetic waves are radiated into space whenever a moving electron changes its direction of motion. Electrons are caused to surge backwards and forwards rapidly in the transmitting aerial, thus radiating waves.

What is the principle of Wireless Reception ?

The electro-magnetic waves sent out

from the transmitting aerial cause electrons in the receiving aerial to flow backwards and forwards in a similar manner to the electrons in the transmitting aerial. This causes minute currents to flow into the receiving apparatus and these are magnified, and the resultant energy is caused to operate a loud speaker.

Why are Wireless Components often Screened ?

It has been found that an electromagnetic field will not pass through a metal conductor. Screening pots are, therefore, placed round high frequency coils so that there will be no interaction between contiguous coils or between high frequency and low frequency sides of the receiving circuit.

What is the difference between Screening and Magnetic Shielding ?

Magnetic shielding is used to isolate the interior from the effects of magnetic fields. The shield must be made of magnetic material such as soft iron, which provides a good path for the magnetic flux. In the case of screening from an electric field, the screening material must be a metal which is a good conductor of electricity.

THE ACCURACY OF H.T. READINGS

WHEN using a three-range voltmeter it is important to remember that the H.T. voltages are not accurate when a high resistance is included in the anode circuit of the valve under test. Anode bend detectors followed by resistance capacity coupling are the valves which have a very high resistance in the anode circuit. The most accurate results are obtained by using the 500-volt range.

As an example, suppose a detector valve has a resistance amounting to 100,000 ohms in the anode circuit, and the voltage reading obtained on the 500-volt range is 100 volts, the extra drop due to the meter current, only $\frac{1}{5}$ of a milliampere, would be 20 volts. A further correcting factor is, however, necessary because, owing to the lowering of the anode voltage, the valve passes less current. When the value of the anode resistance is known, the true value of the anode voltage can be calculated from the following :—

$$E = V + \frac{V \times R}{x} - \frac{R(I_1 - I_2)}{1{,}000}$$

where

E = true anode voltage.

V = voltmeter reading.

R = anode circuit resistance in ohms.

x = voltmeter resistance (500,000 ohms for 500-volt range).

I_1 = anode m.a. with voltmeter disconnected.

I_2 = anode m.a. with voltmeter reading V volts.

In the example just given, where the voltmeter reads 100, and the anode resistance is 100,000 ohms, the true anode volts would be 110 if the difference in the anode current readings with the voltmeter on and off is $\frac{1}{10}$ milliampere.

The Voltmeter Position

Reference to Figs. 10–14 on pp. 285 and 286 of the article entitled " How to Make a Valve and Set Test " will show that the voltmeter is connected, not directly to the anode of the valve, but to the positive side of the milliammeter jack. By arranging the circuit in this way, the current taken by the voltmeter is not registered on the milliammeter. This gives the most accurate arrangement, because the voltage drop due to the milliammeter is only ·075 volt, which is a negligible fraction of the reading on the voltmeter.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION II—DIRECT AND ALTERNATING CURRENTS

IN the diagram of Fig. 1 the arrows show the direction of the stream of electrons which constitute the current in the wire XY due to the battery B. The electrons are available at the — side of the battery and pass through the wire to the + side of the battery. They pass in one direction only, viz., from X to Y, and hence the current which they form is called a UNIDIRECTIONAL CURRENT, or more simply, a DIRECT CURRENT (D.C.). The current obtained from all types of batteries and accumulators is a direct current. For instance, the current which heats the valve filaments in the case of a battery-operated receiver is direct current. Certain types of dynamos also generate D.C., and these are called D.C. dynamos to distinguish them from another form of dynamo called the A.C. dynamo, and which is usually called an alternator. The current obtained from the A.C. dynamo is an ALTERNATING CURRENT—hence the name of the machine.

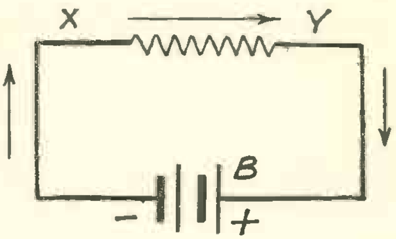


Fig. 1.—DIAGRAM SHOWING THE DIRECTION OF THE STREAM OF ELECTRONS WHICH CONSTITUTE THE CURRENT IN THE WIRE XY DUE TO THE BATTERY B.

What an Alternating Current does

An alternating current is the opposite to a unidirectional current. Instead of passing through its circuit in one direction only it passes backwards and forwards alternately and at regular intervals. In the circuit of Fig. 2 S is a source of alternating current, say an alternator or the A.C. mains supply used for domestic lighting and power, and PQ is a resistance. It might be pointed out here that the symbol in Fig. 2 at S is the conventional symbol for a source of alternating current and is widely used in radio and electrical work.

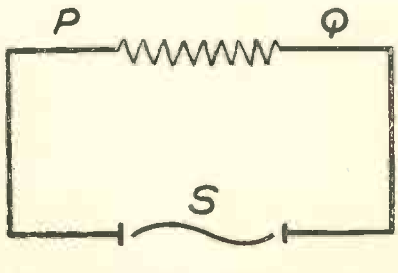


Fig. 2.—IN THIS CIRCUIT S IS A SOURCE OF ALTERNATING CURRENT AND PQ IS A RESISTANCE.

Electrons Passing in a Wire

When we switch on the supply by means of the main switch current immediately begins to pass through the resistance from, say, P to Q. Suppose that at the end of $\frac{1}{600}$th of a second 50 electrons are passing from P to Q, that at the end of the next $\frac{1}{600}$th of a second—*i.e.*, at the end of $\frac{2}{600}$ths of a second from the moment of switching on—90 electrons are passing from P to Q. At the end of $\frac{3}{600}$ths of a second from the beginning 100 electrons will be passing from P to Q. After another $\frac{1}{600}$th of a second the number has reduced to 90, then to 50, and, at the end of $\frac{6}{600}$ths of a second, no electrons are passing through the wire. The electrons now start to move in the opposite direction—*i.e.*, they alternate. At the end of the next $\frac{1}{600}$th of a second ($\frac{7}{600}$ths of a second from the beginning) 50 electrons are passing from Q to P, and the whole process can be shown in a chart thus :—

Time.*	Number of Electrons.	Direction.
start	0	—
1	50	P to Q
2	90	P to Q
3	100	P to Q
4	90	P to Q
5	50	P to Q
6	0	—
7	50	Q to P
8	90	Q to P
9	100	Q to P
10	90	Q to P
11	50	Q to P
12	0	—
13	50	P to Q
14	90	P to Q
15	100	P to Q
16	90	P to Q
17	50	P to Q
18	0	—
etc.	etc.	etc.

* The time is given in 600ths of a second.)

The process continues to repeat itself in this way until the current is switched off. Instead of using this chart to show the number of electrons passing in the wire PQ we can draw the graph of Fig. 3, and we gain the advantage that intermediate values can be seen at a glance.

Cycles and Frequency

The graph shows quite clearly that the whole CYCLE of events OABCD repeats itself from D to H and continues to repeat regularly (the mathematician says PERIODICALLY). The first cycle from O to D occupies $\frac{12}{600}$ths of a second—*i.e.*, $\frac{1}{50}$th of a second—the second cycle takes $\frac{1}{50}$th of a second, and, in fact, every COMPLETE CYCLE occupies $\frac{1}{50}$th of a second. Another way of expressing this fact is to say that there are 50 CYCLES in each second. The number of cycles is called the FREQUENCY, and hence the frequency, in this case, is 50 CYCLES PER SECOND. The portion of the curve OAB is called a HALF CYCLE, and BCD, DEF, and FGH are also complete half cycles.

Distinguishing between two Directions of Current

The graph of Fig. 3 is frequently drawn with the Time Axis horizontal, as shown in Fig. 4. In this graph it will be seen that the " P to Q " half cycles are marked with a + sign, and the " Q to P " half cycles with a − sign. This is the mathematician's shorthand way of distinguishing between the two directions of the current. He calls one direction the positive (+) direction and the other the negative (−) direction. It would not matter which direction we take as + provided that we are consistent about it.

Now the number of electrons passing in a circuit at any particular moment determines the current in the circuit. The greater the number of electrons the greater the current, and *vice versâ*. Thus the graph of Fig. 4 also shows how the current in the wire PQ (see Fig. 2) varies. For $\frac{1}{100}$th of a second—*i.e.*, the time the first half cycle lasts—the current is in the positive direction (P to Q) and for the next $\frac{1}{100}$th of a second it passes in the negative direction, and repeats the complete alternations at a frequency of 50 cycles per second.

Periodic Time

In the particular example we have just considered the frequency was 50 cycles per second, but the frequency of domestic electric supplies in this country varies from 40 to 60 cycles per second, and in a few instances it is only 25 cycles per second and in other cases it is 100 cycles per second. That is to say, the complete cycle of events, represented by OABCD in Figs. 3 and 4 occurs 25, 40, 45, 50, 60, or a 100, etc., times in each second. Therefore the time taken to perform one complete cycle—often called the PERIODIC TIME—is $\frac{1}{25}$, $\frac{1}{40}$, $\frac{1}{45}$, $\frac{1}{50}$, $\frac{1}{60}$, or $\frac{1}{100}$th, etc., of a second respectively.

What happens during one Complete Cycle

Let us examine carefully the rise and fall and the reversal of the current during one complete cycle. The current rises to its greatest positive value (*i.e.*, its MAXI-

MUM positive value) in a quarter of the time taken for the complete cycle; it is zero at half-time; it reaches its maximum negative value in three-quarters of the periodic time; it is zero at the end of the periodic time. Whatever the frequency, the same sequence of events occurs. The value of the current at any moment is called the AMPLITUDE, or the CURRENT AMPLITUDE. Consider the point P on the complete cycle shown in Fig. 5. PV and PH are the vertical and horizontal lines which show that the point P is reached in one-third of the time taken to reach the maximum positive amplitude, and that the actual amplitude at P is one-half of the maximum amplitude. Whatever the frequency, the time taken by the current to reach half its maximum amplitude is always one-third of the time taken to reach the maximum amplitude. A similar statement can be made regarding the time taken to reach any other value of amplitude. In fact, the shape of the graph representing the current is always a curve of the type shown in the diagrams.

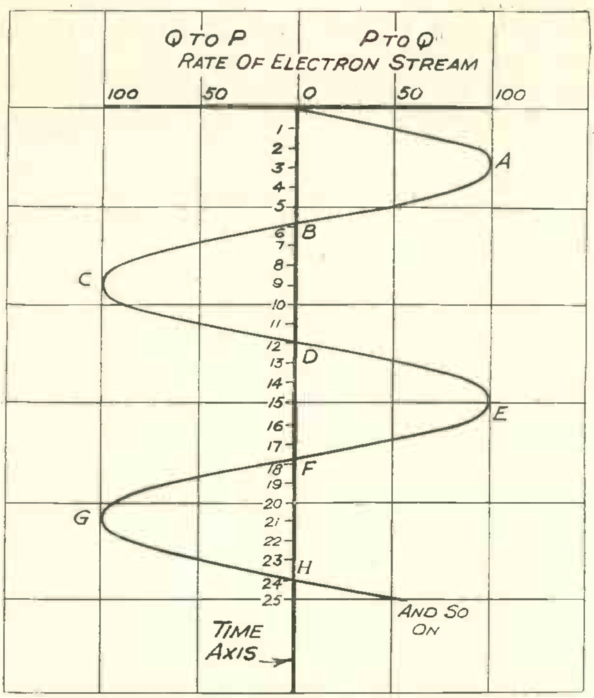


Fig. 3.—GRAPH SHOWING HOW AN ALTERNATING CURRENT IS MADE UP.

Note.—Time is measured in 600ths of a second.

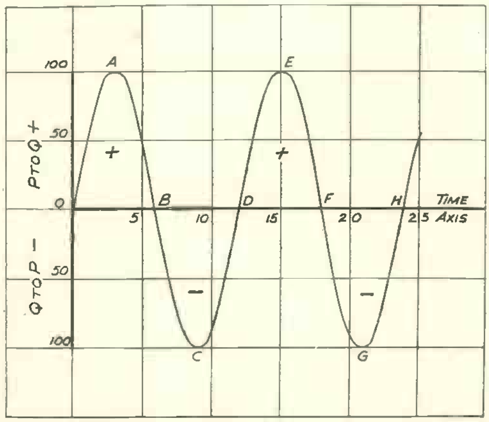


Fig. 4.—GRAPH BY MEANS OF WHICH THE TWO DIRECTIONS OF THE CURRENT CAN BE DISTINGUISHED.

Abbreviations referring to Alternating Current

We have seen that the mathematician uses his shorthand notation to save himself both time and trouble, hence he has certain abbreviations which he uses when referring to alternating currents, viz.:

T = The periodic time in seconds —*i.e.*, the time taken for one complete cycle to occur.

f = The frequency in cycles per second —*i.e.*, the number of complete cycles occurring in each second.

I_0 = The maximum current which passes in the circuit. It is reached twice in each cycle, once in the positive half cycle, and once in the negative half cycle, and it is represented by the lines MA and NB in Fig. 5. (The small o after the I in I_0 is called a SUFFIX.)

Sine Curves

Just as we used an equation, or formula, to express the results of Ohm's experiments in a concise manner, so we can embody the whole of the foregoing explanation of alternating currents in a single equation. The graph we have been discussing is very well known to the mathematician and is called a SINE CURVE. It is represented by the following equation :—

$$I = I_0 \sin 2\pi ft \quad . \quad . \quad (1)$$

The term "sin" is an abbreviation of "sine" and is pronounced in the same way as the word "sign." The term "π" is the greek letter "pi" (pronounced "pie") and is familiar to most people by virtue of its use in connection with circles. It is a constant number, its value being $= 3\frac{1}{7}$, approximately, or more accurately $= 3{\cdot}1416$. I is the amplitude of the current at any moment. (Readers who wish to know more about the sine curve should read first Ralph Stranger's *Mathematics of Wireless* and then an elementary textbook on trigonometry for electrical engineers, or an elementary textbook on alternating currents.)

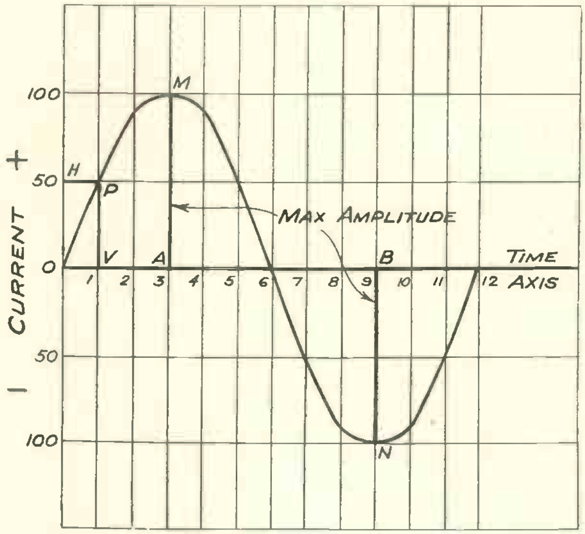


Fig. 5.—GRAPH SHOWING ONE COMPLETE CYCLE.

Expressing Periodic Time

In the particular cases we were considering earlier we saw that the periodic time was always obtained by dividing 1 by the frequency, and we express this in our shorthand notation thus :—

$$T = \frac{1}{f} \quad . \quad . \quad . \quad (2)$$

Another way of saying the same thing is of course :—

$$f = \frac{1}{T} \quad . \quad . \quad . \quad (3)$$

Any reader who is in doubt about this can demonstrate the truth of it by taking an example.

A current cannot pass through a circuit unless accompanied by a voltage across the ends of the circuit, and conversely. It does not matter whether we think in terms of the current or the voltage, they are merely different aspects of the same happening. We have seen that a direct current passing through a wire produces a steady voltage across its ends, and conversely, that a steady voltage connected across the ends of a wire causes a unidirectional current to pass through the wire. In the same way an alternating current passing through a wire produces an alternating voltage across its ends, and conversely, an A.C. voltage applied across a wire causes an alternating current to pass through the wire. The mathematical shorthand for an A.C. voltage is similar to that for an alternating current, thus :—

$$E = E_0 \sin 2\pi ft \quad . \quad . \quad (4)$$

In this equation E is the VOLTAGE AMPLITUDE, and E_0 is the MAXIMUM VOLTAGE AMPLITUDE. These correspond to I and I_0 which we used for current amplitude and maximum current amplitude respectively.

Effect of Alternating Current on a Circuit

The effect of an alternating current or voltage on a circuit is different from that of a direct current or voltage. In the latter case the amplitudes of both current and voltage are steady, whereas in the first case the amplitudes both alternate periodically from zero to a positive maximum, back to zero and to a negative maximum, and back again to zero. The effect in an A.C. circuit is the *average effect* of the voltage and current, and the average can be calculated with the aid of mathematics. We shall only concern ourselves now with the result of the calculation. The average effect of the current $= \frac{I_0}{\sqrt{2}}$, and of the voltage $= \frac{E_0}{\sqrt{2}}$ (the sign $\sqrt{\ }$ is a "square root" sign and $\sqrt{2}$ means "the number which, multiplied by itself, gives 2 as an answer." The answer is $\sqrt{2} = 1{\cdot}4$, approximately. The average effects—*i.e.*, $\frac{I_0}{\sqrt{2}}$ and $\frac{E_0}{\sqrt{2}}$—are known as the ROOT MEAN SQUARE values, written R.M.S., and the values I_0 and E_0—see equations (1) and (4)—are known as PEAK VALUES.

When we are told by the electric supply company that the mains supply is 240 volts of A.C. at 50 cycles per second, the 240 figure is the R.M.S. value. Hence :—

$$240 = \frac{E_0}{\sqrt{2}},$$

and the peak value is seen to be :—

$$E_0 = 240 \times \sqrt{2} \text{ volts.}$$

i.e., $E_0 = 240 \times 1{\cdot}4$ volts.

Thus, $E_0 = 336$ volts.

The ammeters and voltmeters used for all ordinary measurements of current and voltage in A.C. circuits only measure R.M.S. values, thus an A.C. voltmeter connected across the A.C. mains, in the example just quoted, would read 240 volts.

QUESTIONS AND ANSWERS

What is meant by a Direct Current ?

A steady flow of electrons in one direction through an electric circuit.

What are the chief sources of Direct Current ?

A., a primary battery such as grid bias battery or H.T. battery.

B., an accumulator.

C., a dynamo.

What is meant by an Alternating Current ?

A flow of electrons alternately backwards and forwards through an electric circuit.

What is the chief source of an Alternating Current ?

An alternator, which is used in power stations to generate electricity on a large scale.

What is meant by the Frequency of an Alternating Current?

By frequency is meant the number of complete reversals which take place in a second. Thus, the current starts at zero, rises to a maximum in a positive direction, then falls to zero and attains a maximum in a negative direction and returns again to zero. This forms a complete reversal or cycle.

What is meant by the Periodic Time of an Alternating Current ?

The time taken for a complete cycle. Thus, if the frequency is 50 cycles per second, the periodic time is one-fiftieth of a second.

What is the average value of an Alternating Current ?

The average value of the current is zero because it will be found that the positive half cycles exactly balance the negative half cycles.

How could you demonstrate the above Fact ?

By passing an alternating current through a direct current ammeter, when it would be found that the needle is not affected, or only quivers slightly.

How is it then that lamps can be lighted from an A.C. supply as well as from a D.C. supply ?

Because the heating (and lighting) effect depends upon the square of the current. A negative quantity when squared becomes positive, and in this way the effects of positive and negative half cycles add up.

THE PENTODE VALVE

By S. R. MULLARD, M.B.E., M.I.E.E.

In this article one of the leading experts in the wireless industry deals with some of the most interesting characteristics of the Pentode.

ONE of the most marked features of radio design and development during the past few years has been the attention given to the output stage of radio receivers, and particularly to the production of valves for use in that stage.

It has been realised by radio engineers that the transformation of the radio programme from audio frequency voltage variations into audible air vibrations constitutes a series of problems upon the solution of which the perfection of radio reproduction largely depends.

A noteworthy result of these researches was the development of the pentode or five-electrode output valve. This valve, particularly in combination with the latest types of speaker, provides an output stage having remarkably high electrical efficiency, and capable of a very high standard of reproduction.

Further Developments Likely

As there are signs that the future may see further important developments of the Pentode, possibly the introduction of pentodes of still larger output, some description of the operation of this class of valve will be of general interest.

Before the particular virtues of the pentode valve can be appreciated, it is necessary to have a clear idea of what is going on in the loud speaker connected to the output stage.

How High Note Losses Occur

The loud speaker may be regarded as a motor doing work on the air surrounding it and as a result of this and the copper loss in the moving coil, the whole device displays a resistive characteristic to alternating currents of speech and musical frequencies. Unfortunately, however, this is not true when the whole range of audio frequencies is considered, for the following reasons :—

(*a*) At the higher musical frequencies, the mass of the coil and the middle of the cone plays an increasingly important part, in that it tends to prevent proper movement of the cone.

The effect is exactly equivalent to that which would be obtained if an inductance were interposed between the source (output valve) and a perfect speaker. Then, assuming constant A.C. voltage at the source and increasing frequency, there would be less power expended in the speaker as the frequency rises. Any "free" (leakage) inductance contributed by the

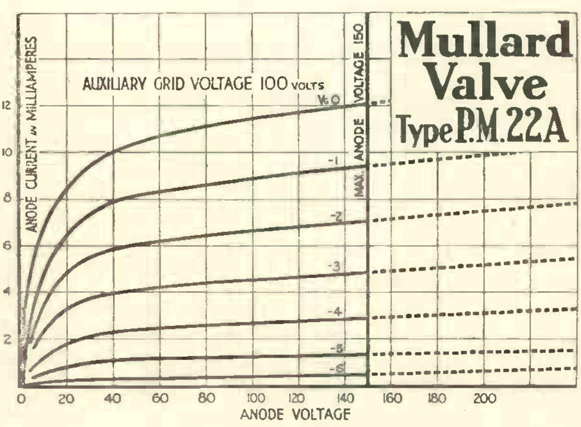


Fig. 1.—CHARACTERISTIC CURVES OF P.M.22A PENTODE VALVE.

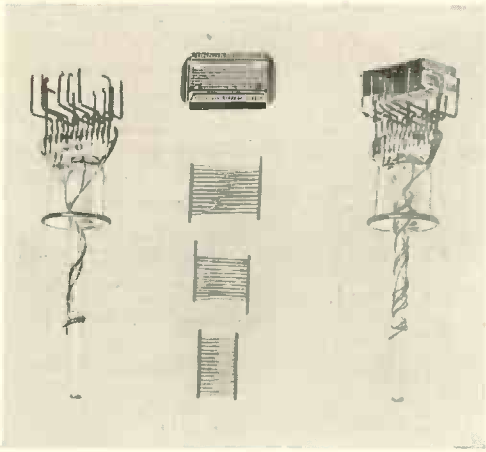


Fig. 2.—A Stage in the Construction of a Pentode Valve.

Showing assembly of foot of electrodes.

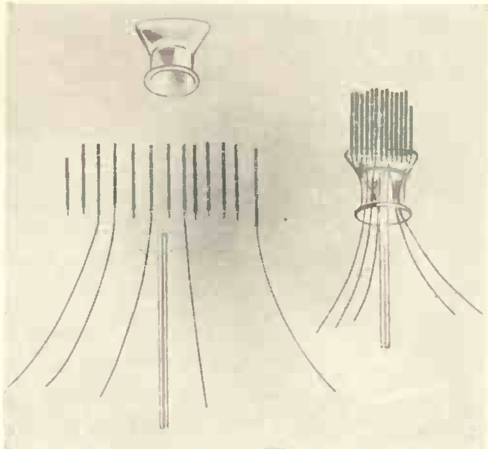


Fig. 3.—A Stage in the Construction of a Pentode Valve.

This shows parts of foot and completed foot.

output transformer similarly reduces the higher frequencies.

Loud Speaker Losses at Low Frequencies

(*b*) At the very lowest frequencies in the musical gamut, the resilience of the coil-locating device and the diaphragm surround become apparent and this also is equivalent to a reactance in series with the "working" impedance of the speaker, again reducing the available energy, but at the lower end of the range. This reactance is, in effect, capacitative, *i.e.*, the current wave leads the voltage wave and the effect varies inversely as the frequency.

From (*a*) and (*b*) above, it will be seen that some attenuation is inevitable at both extremes of the musical scale if a triode output valve is used, which can be regarded as a generator with a substantially constant e.m.f. since the current through the coil decreases at the highest and lowest frequencies.

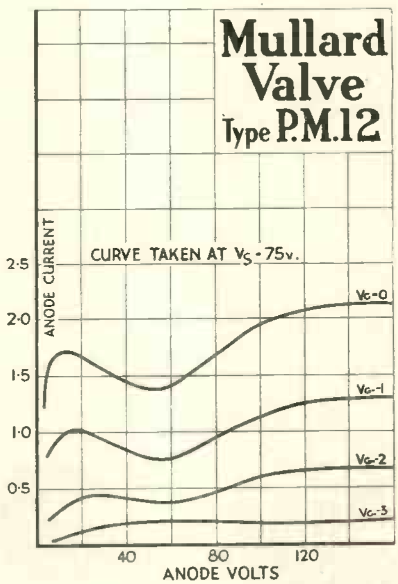


Fig. 4.—Characteristic Curves of a P.M.12 Valve.

Why the Pentode avoids these Losses

It is one of the outstanding advantages of the pentode valve that, over quite a wide range of external impedances, it is a *constant current* device. This is due to the fact that the differential internal resistance, generally called "impedance" (not a scientifically accurate description of the quantity) is commonly many times greater than the impedance presented by the load (the loud speaker), thus the valve itself largely determines the magnitude of the speech currents in the stage.

It follows that the reactance effects mentioned earlier, due to what might be termed mechanical reactances, are no longer harmful when a pentode is used, as the increased impedance results in a relatively small decrease only in the load current.

CONSTRUCTION OF THE PENTODE

The pentode valve is a development of the screened grid tetrode * now universally used for high frequency and amplification, and we shall see how the special requirements of the output stage necessitate the special pentode form.

Why the S.G. Valve cannot be used as an Output Valve

Referring to the curves (Figs. 1 and 4) it will be seen that in the particular valve shown, which is representative, there is an initial rise of anode current with voltages up to approximately 20 volts, after which there is a negative resistance portion, *i.e.*, that part of the curve where an increase of the anode voltage results in a reduction of anode current. This effect, which stops before the anode voltage becomes equal to the screening grid voltage, is due to secondary emission from the anode back to the screen grid. Finally, when Va is much greater than Vs, we get a linear characteristic of high differential resistance, *i.e.*, $\frac{\delta Va}{\delta Ia}$ is large.

* Four electrode valve.

Fig. 5.—The Complete Foot Assembly ready for sealing in Bulb.

Why it can be used as a H.F. Amplifier

This part of the curve is useful for amplification purposes, since various changes of the control grid voltage result in almost exactly corresponding changes of anode current. The

Fig. 6.—The Complete Foot, Bulb and Sealed-in Bulb.

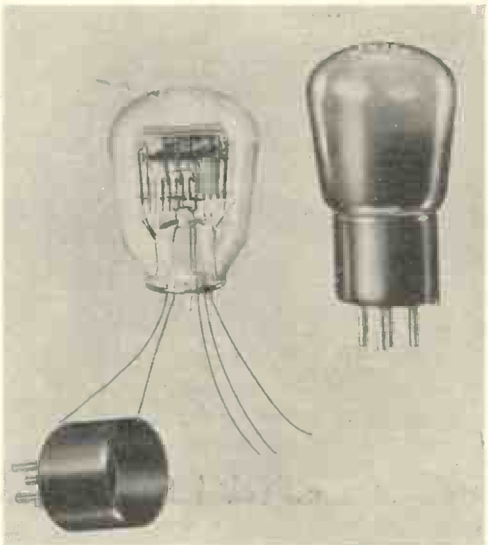


Fig. 7.—Left, Valve exhausted and ready for capping. Right, Valve capped and finished.

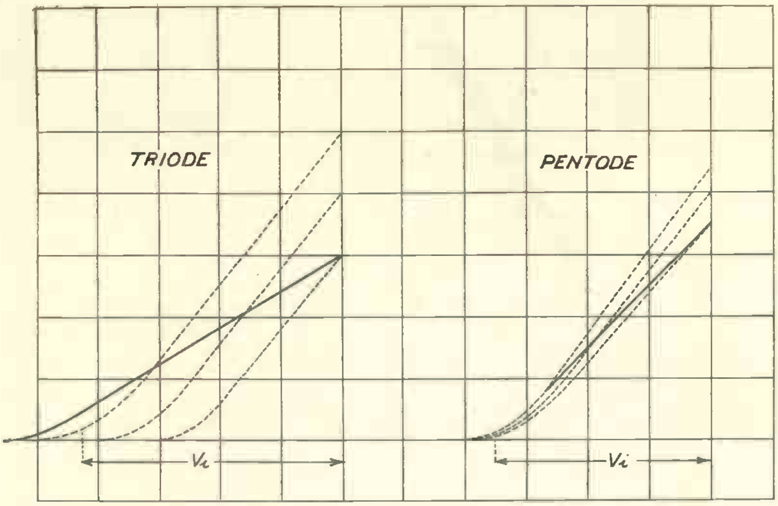


Fig. 8.—Showing that an increase of Anode Current will not be checked by Falling Anode Volts.

initial "kinks" in the S.G. characteristic are not disadvantageous in a H.F. amplifier, for the input H.F. voltages will range from about 10 microvolts to perhaps 50 millivolts, resulting in changes of anode volts up to about 5 volts R.M.S. (7 volts peak) in an extreme case. Such a variation is clearly permissible without departing from the linear portion of the curves.

What an Output Valve should be capable of

The most desirable feature of the output valve, however, is that it must be capable of large variations in anode voltage and current, without reaching the region of curved characteristics, and this is clearly impossible with the simple S.G. valve. To remove the "hills and dales" from the tetrode characteristic it is necessary to prevent the back-emission from anode to screen mentioned earlier and the most obvious way of doing this is to remove the anode some distance from the other electrodes.

How Secondary Emission is Prevented—The Pentode

There are, however, certain disadvantages attached to this method, notably bulky construction and a somewhat serious diminution of Ia before the hump is "ironed out." Accordingly, the desired characteristics are brought about by interposing a third grid, of open mesh and fine wires, between the normal auxiliary grid and anode, which is joined to the cathode (or the middle of the filament in a directly heated valve). This effectively prevents any secondary anode emission, and we get the type of characteristic shown in Fig. 1.

The most important Characteristic of the Pentode

As pointed out earlier the pentode is substantially a constant current device, and inspection of the characteristic curves reveals that there is little variation of Ia over the major part of the range of anode voltage. It is this part of the characteristic which is used in the output amplifier.

OPERATION

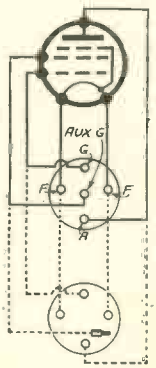


Fig. 8a.—Showing Arrangement of Pentode Terminals.

One of the attributes of the pentode is high sensitivity and this again is really due to the constant current feature.

When the output stage is excited by the application of a signal to the control grid, large variations of anode voltage take place, because the A.C. voltage produced by the signal is, in effect, superimposed on the battery volts, being in opposition to the battery volts during one half of each cycle and assistant in the other. For example, a small output valve having 150 volts steady potential at the anode might display fluctuations of ± 100 volts. That is, the anode potential might vary between 50 and 250 volts.

What happens in the Case of a Triode

Now, in the case of a triode, the phenomena producing these fluctuations tend to cancel in the following manner: The steady battery voltage is split up between the valve and the load, which are of comparable impedances and when a positive impulse is impressed on the grid, the anode current increases, *i.e.*, the apparent resistance of the anode filament path drops, which results in a reduction of anode potential. The resultant increase of anode current will therefore not be so great as would be expected from the applied impulse alone. Similarly, the energy stored in the loud speaker during positive half cycles produces a rise of anode voltage when the grid receives a negative impulse, which tends to prevent the anode current decreasing to the low value expected during such impulses.

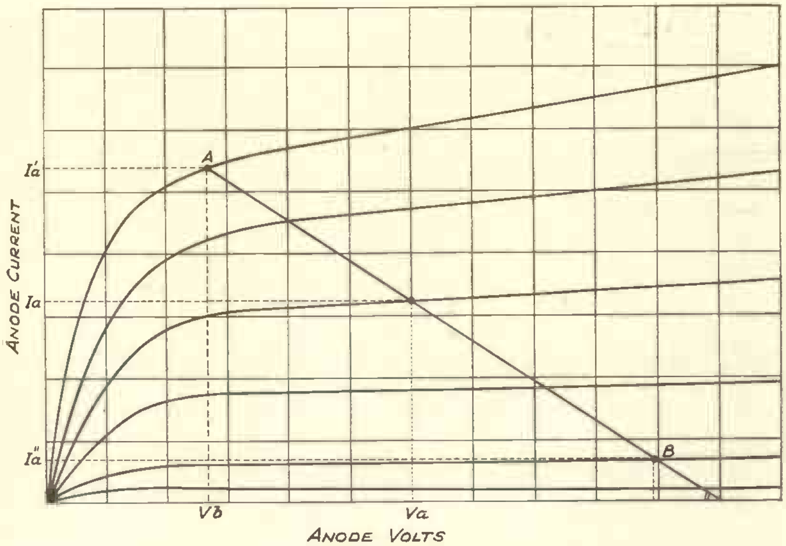


Fig. 9.—Curves of a Hypothetical Pentode.

Another Pentode Characteristic

Further examination of the pentode characteristics shows that an increase of anode current will not be checked by falling anode volts, and *vice versâ*, as the Ia/Va characteristics are nearly horizontal. Reference to Fig. 8 and also to the hypothetical curves shown above will make this point clear. It is assumed that the two valves, of which the Ia/Vg curves are shown have equal slope or mutual conductance. The operating curves are shown as full lines and the normal static curves dashed. The three static curves are shown in each case for the same anode voltages but for one auxiliary grid voltage in the case of the pentode, as this voltage, which largely controls the *anode* current, is unvarying during operation.

" Vi " represents the peak input swing to be applied in each case, and it will be seen that this is materially less in the case of a pentode.

The Output Load

It is well known that the impedance of the load in the case of a triode valve bears a direct relation to the so-called valve impedance, varying in practice between equality and four times that of the valve for the limiting cases. No similar direct relation exists in the pentode case, where the load is usually *less* than the valve impedance.

The Pentode does not impose a Heavy Drain on the H.T. Battery

The pentode valve, which was first introduced to the British market by the Mullard Company, in 1928, has achieved a remarkable degree of popularity. At first available only in forms suitable for use in battery-operated domestic receivers, they now comprise an extensive range, including a small pentode operating at the low anode consumption of 4½ milliamps. at 100 volts; large types for all battery receivers; directly and indirectly heated A.C. mains pentodes; and high voltage pentodes giving outputs of several watts, and suitable for use in the largest radio gramophones and in medium sized public address equipments.

SOME INTERESTING EXPERIMENTS ON VALVES

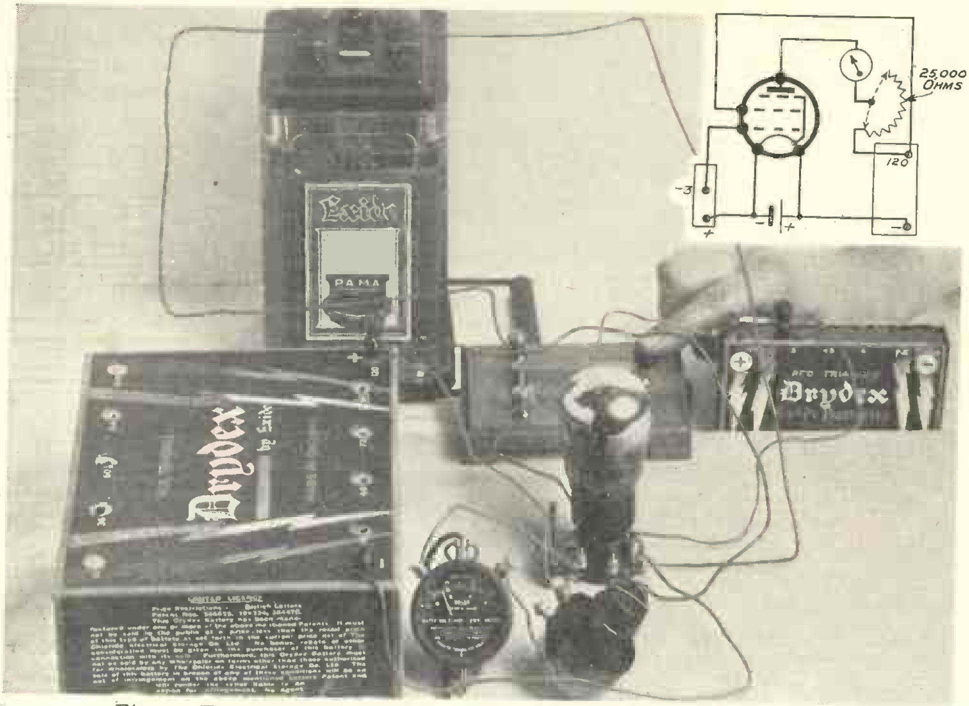


Fig. 1.—Effect of Varying Resistance in Anode Circuit of Pentode.
With resistance cut out, anode current equals 7 milliamps.

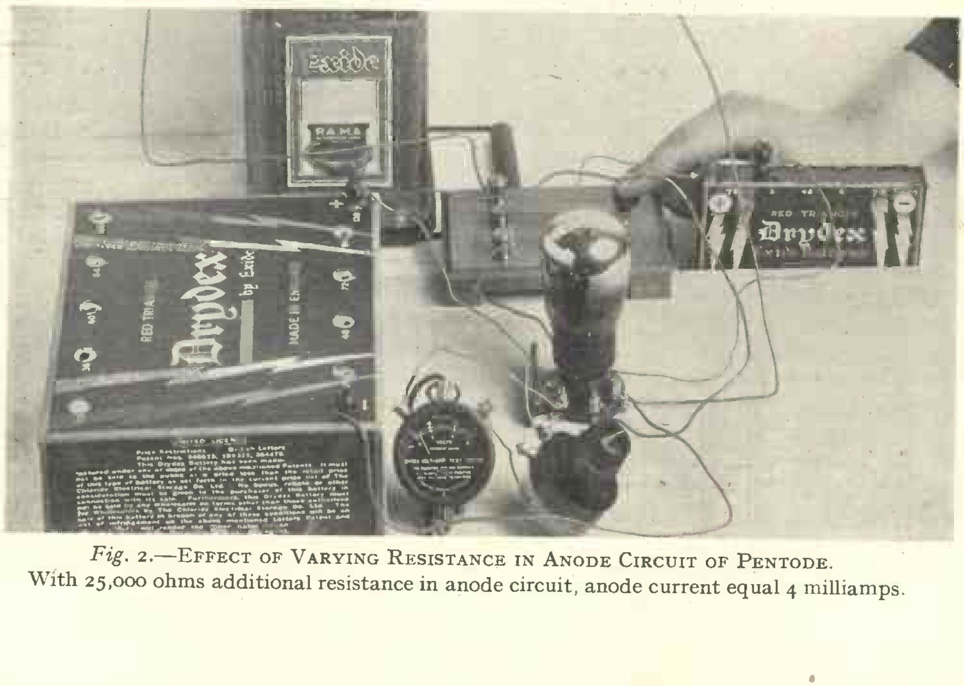


Fig. 2.—Effect of Varying Resistance in Anode Circuit of Pentode.
With 25,000 ohms additional resistance in anode circuit, anode current equal 4 milliamps.

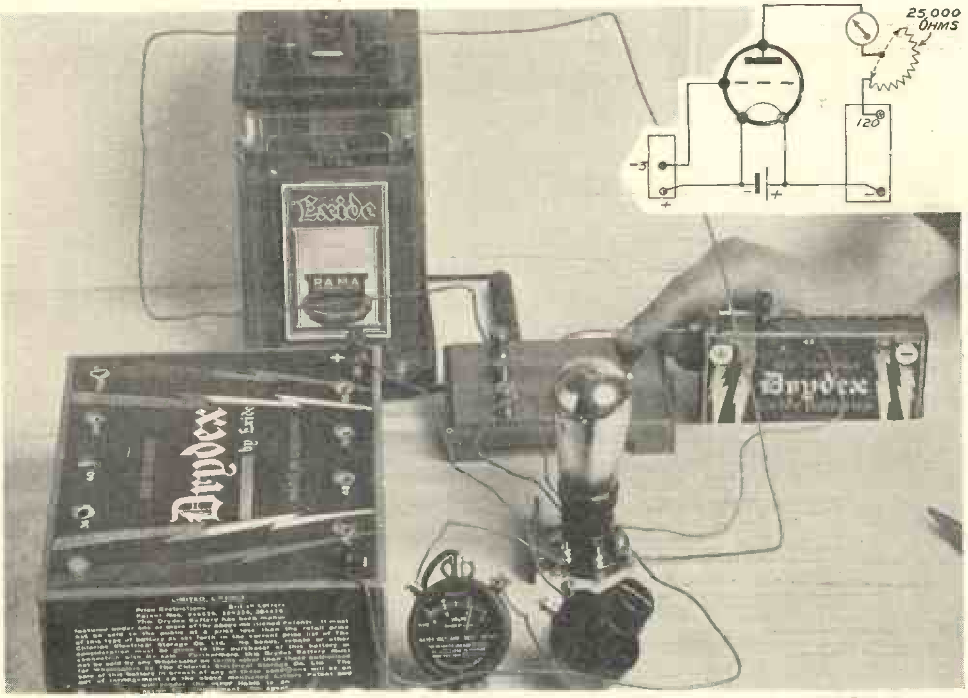


Fig. 3.—THE SAME EXPERIMENT ON A POWER VALVE.
With no extra resistance in circuit anode current equals 22 milliamps.

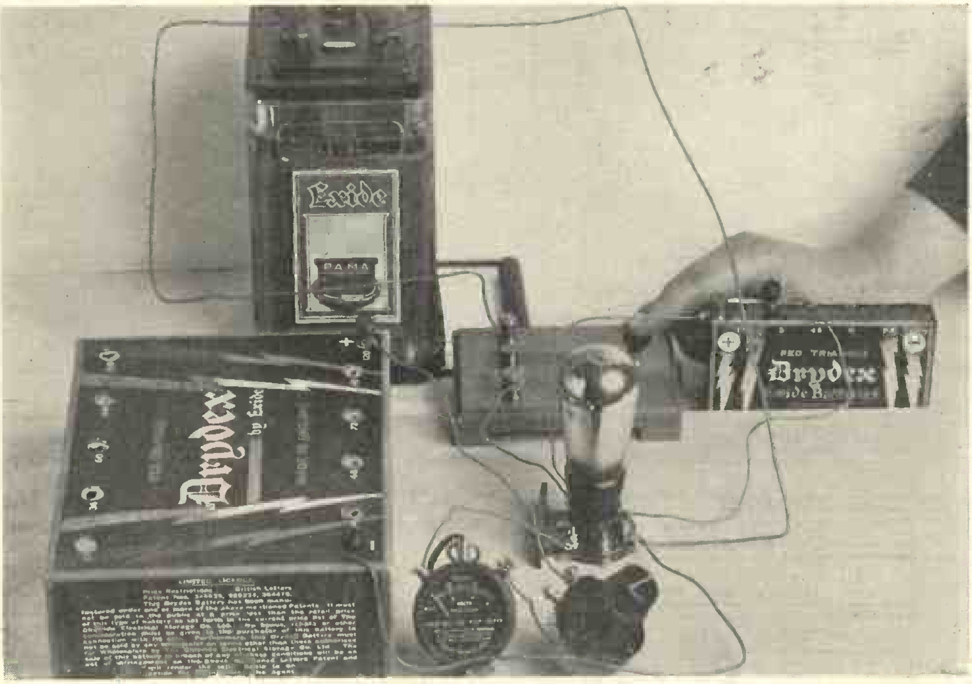


Fig. 4.—THE SAME EXPERIMENT ON A POWER VALVE.
With 25,000 ohms additional resistance in circuit, anode current is cut down to 2 milliamps.

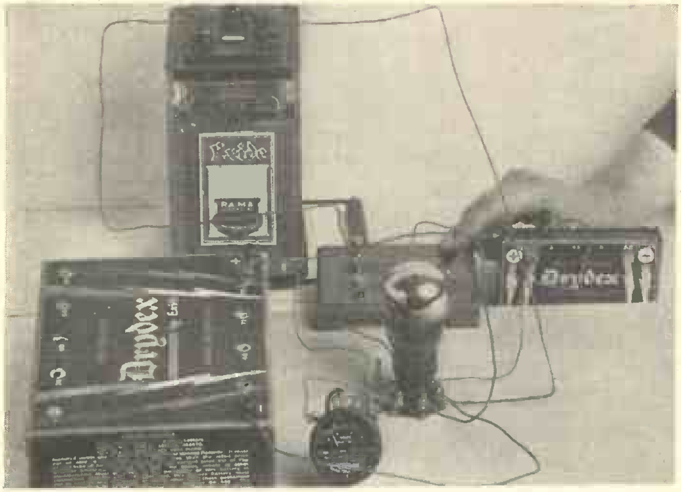


Fig. 5 (Left).—EFFECT OF VARYING ANODE VOLTAGE ON PENTODE VALVE.

Fig. 5A (Right).—EFFECT OF VARYING ANODE VOLTAGE ON PENTODE VALVE.

Anode voltage, 72 volts; anode current practically same as before, namely, about 7 milliamps.

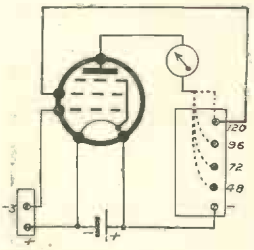
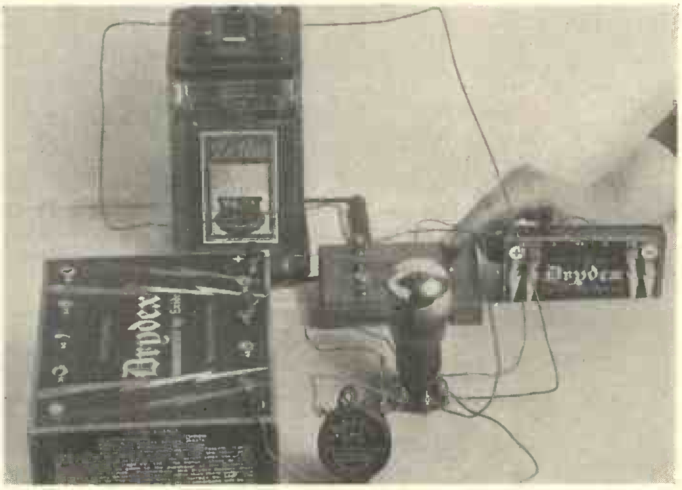


Fig. 6.—CIRCUIT ARRANGEMENT.



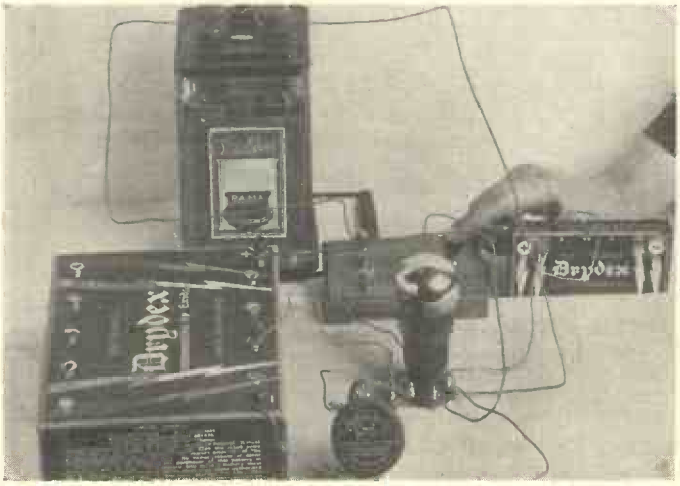
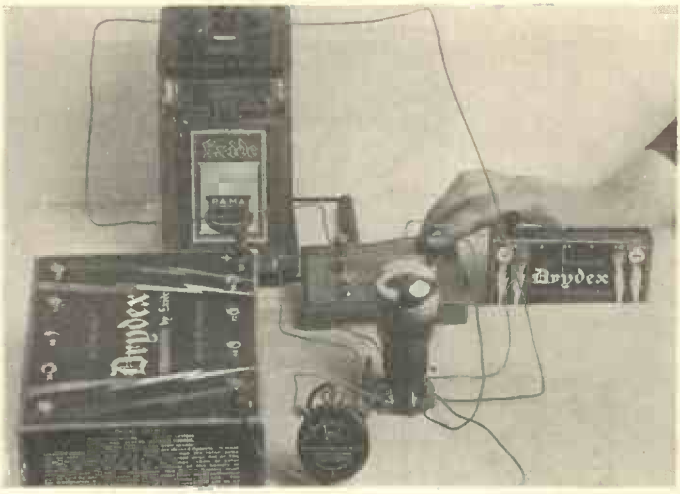


Fig. 7 (Left).—EFFECT OF VARYING ANODE VOLTAGE ON PENTODE VALVE.

Notice that the anode voltage has now been cut down to 48 volts. It will be seen that this alteration of anode voltage has made very little difference to anode current, which still remains at about 6 milliamps. These three pictures illustrate an important characteristic of the pentode.

Fig. 8.—(*Right*) Effect of altering Grid Bias.

The circuit arrangements are shown in Fig. 9a. Note that the auxiliary grid and anode have 120 volts positive. The grid bias reading in the first picture is — 1·5 volts. Note that the anode circuit is about 12 milliamps.



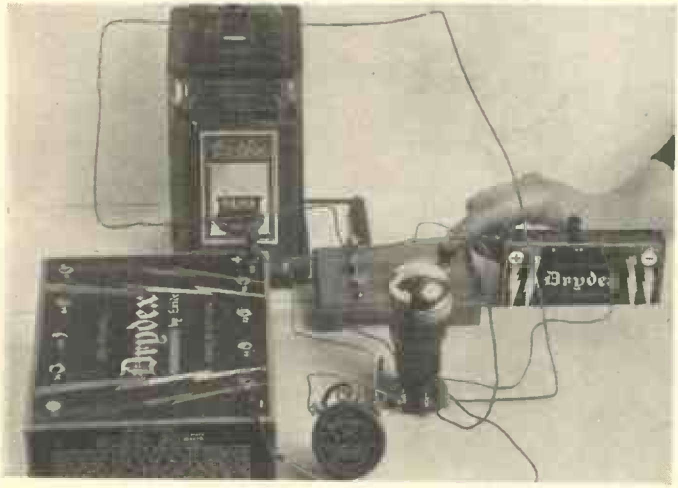


Fig. 9.—(*Left*) Effect of altering Grid Bias.

Note that grid bias is here altered to — 4·5 volts. The anode current is now about 7 milliamps.

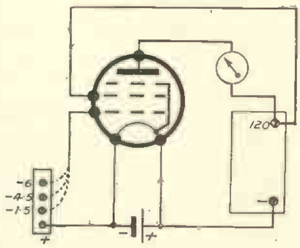
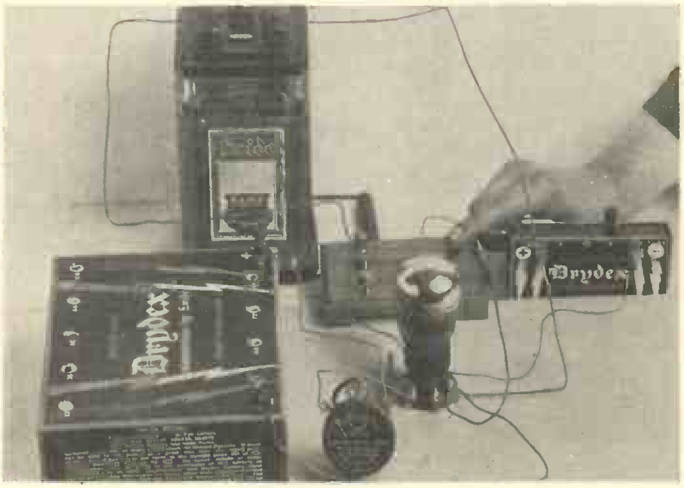


Fig. 9a. — Circuit arrangement.

Fig 10.—(*Right*) Effect of altering Grid Bias.

The grid bias has been increased to — 6 volts. It will be seen that the anode current is now reduced to zero. The pictures on this page show in a striking manner how sensitive the pentode valve is to a variation in the grid voltage. It should be remembered that the useful output of a valve depends not so much on the total anode current, but rather on the fluctuations in anode current. A valve which with a small anode current gives a big variation is more effective than a valve giving a heavy anode current with little variation.



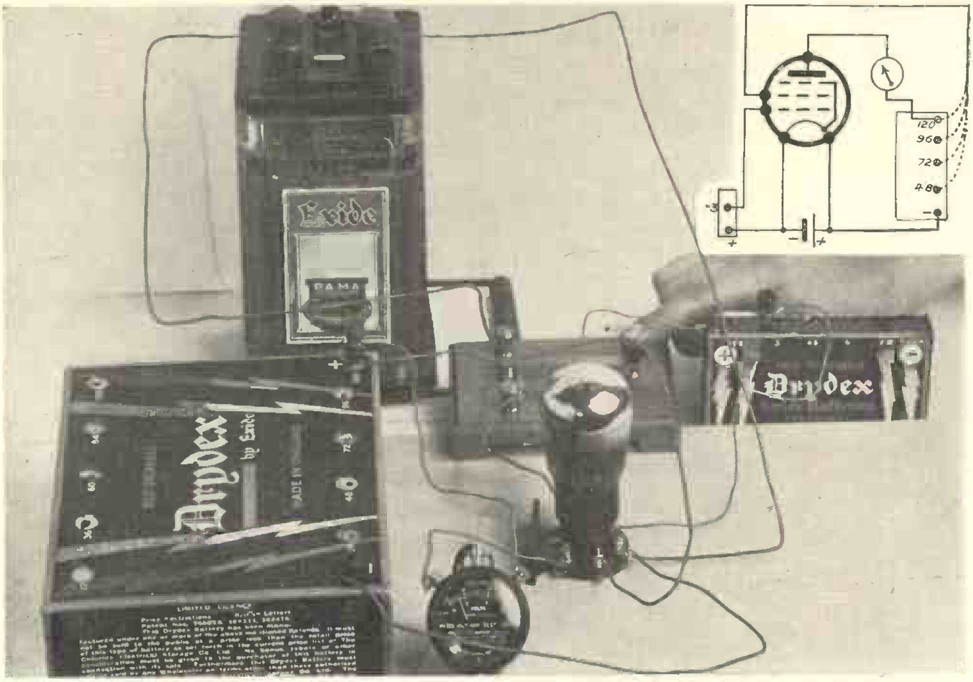


Fig. 11.—Effect of Varying Auxiliary Grid Voltage.
Auxiliary grid voltage, 120 ; anode current, 7·5 milliamps.

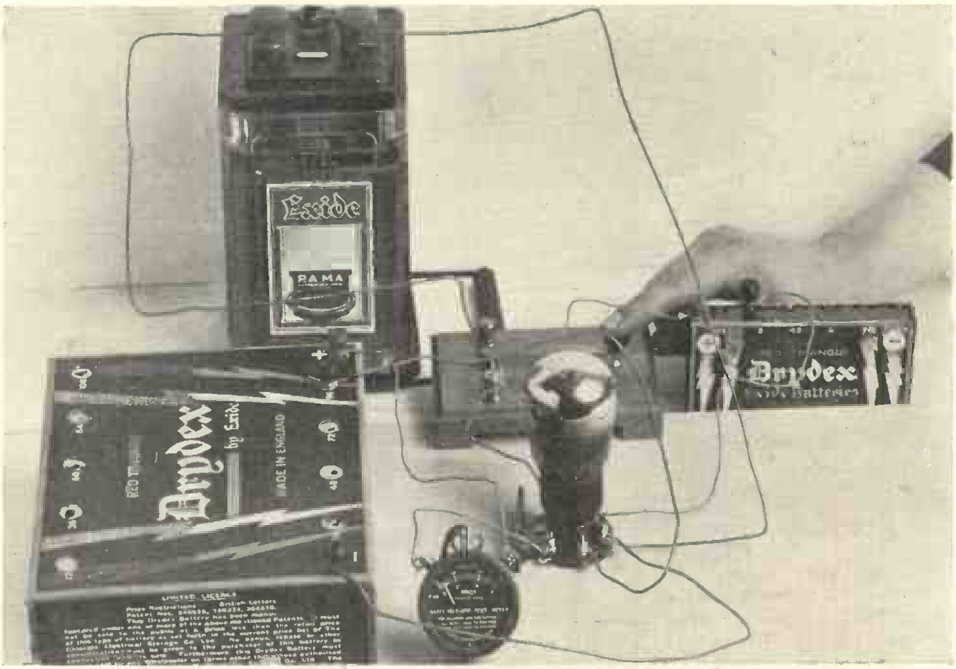


Fig. 12.—Effect of Varying Auxiliary Grid Voltage.
Auxiliary grid voltage, 96 ; anode current, 4 milliamps.

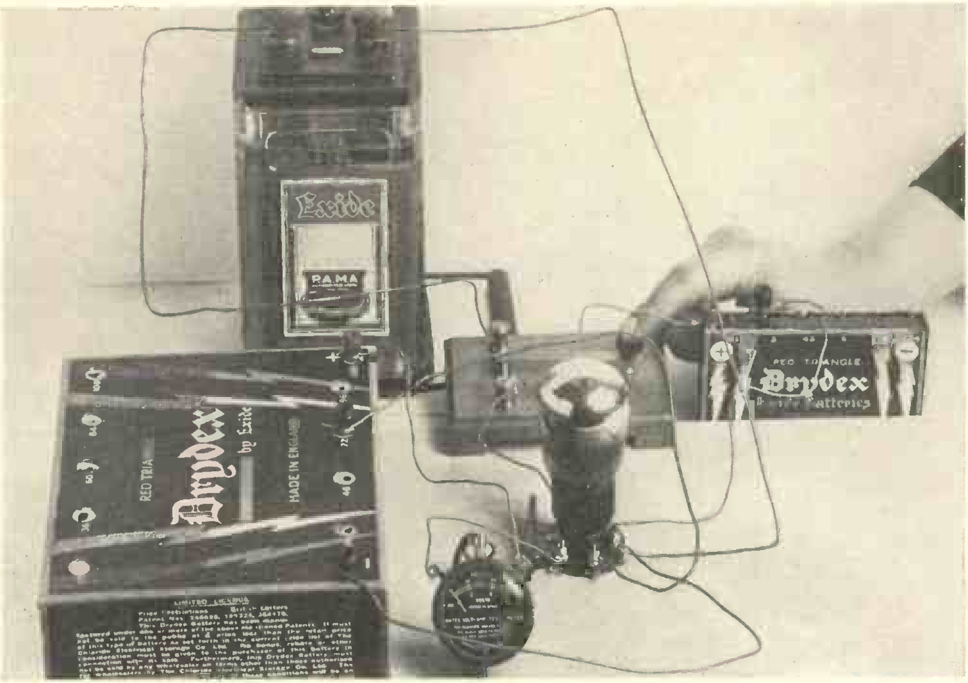


Fig. 13.—EFFECT OF VARYING AUXILIARY GRID VOLTAGE.
Auxiliary grid voltage, 72 ; anode current, 1 milliamp.

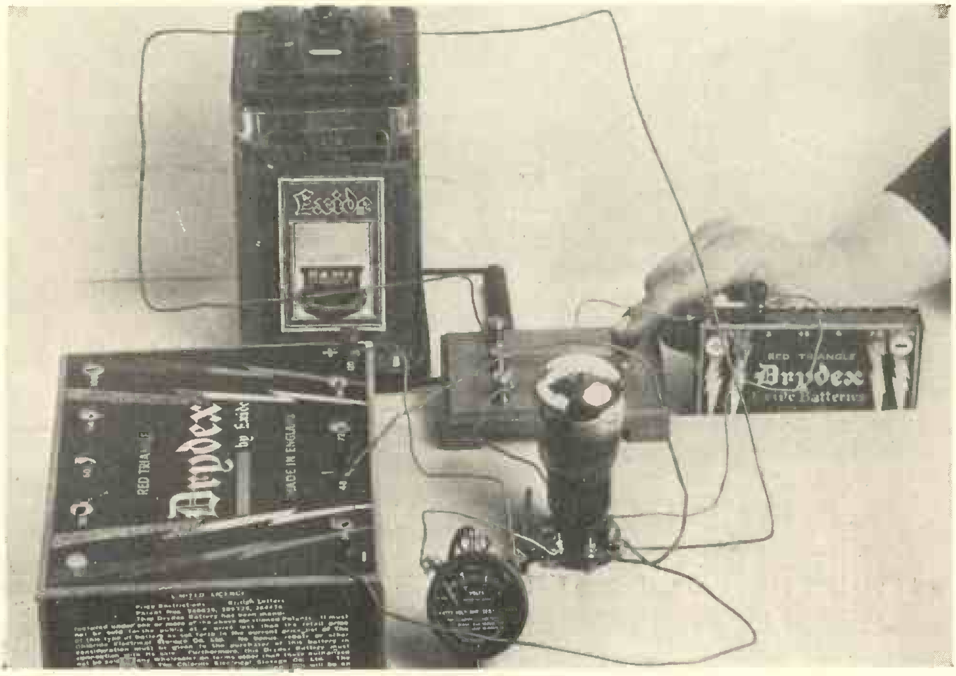


Fig. 14.—EFFECT OF VARYING AUXILIARY GRID VOLTAGE.
Auxiliary grid voltage, 48 ; anode current, 0 milliamps.

OPERATING THE "EELEX" SHORT-WAVE CONVERTER

FOR BATTERY AND A.C. MAINS RECEIVERS

By L. H. FITZ-GIBBON, A.M.I.R.E.

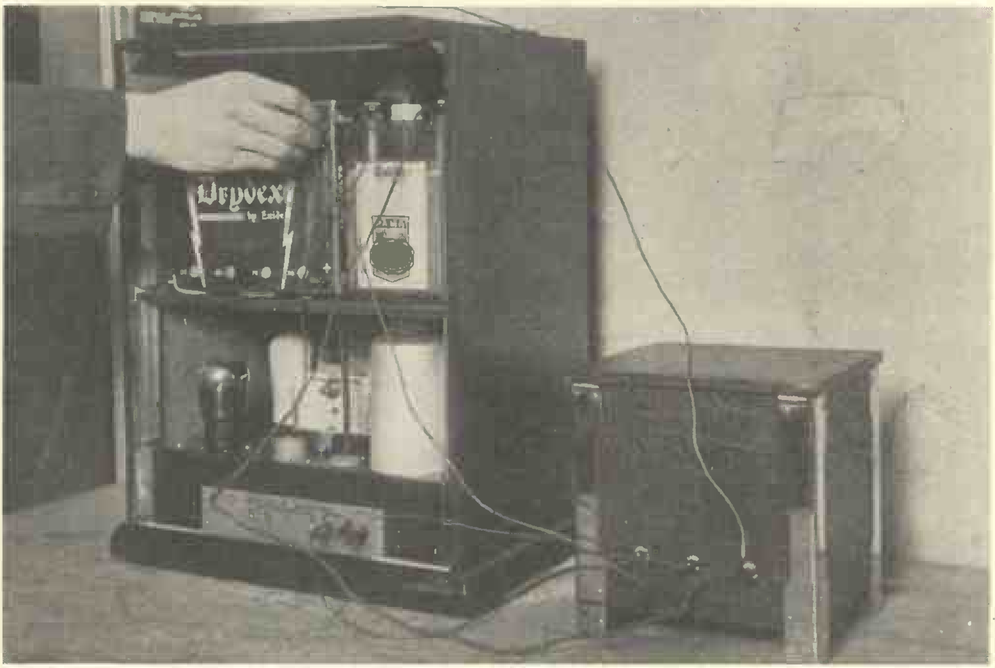


Fig. 1.—How the Converter is connected to a Battery Set.

This shows the converter connected up to a battery set and using the same batteries as the main set.

THE "Eelex" short wave converter employs the supersonic circuit and the valve in the converter is a combined oscillator and first detector. It is essential to use this converter in conjunction with a broadcast receiver which employs one or more stages of screened grid H.F. amplification and another necessary point is that the broadcast set must tune between 1,000 and 2,000 metres. The converter passes a beat note on to the long waves through the long wave coils of the main set, these coils acting as intermediate frequency transformers. The receiver and converter, therefore, become a short wave super-heterodyne set.

The Tuning Range

This converter covers a wavelength range of approximately 16–60 metres. The clip attached to the variable tuning condenser is intended for varying the wavelength and can be placed either half-way up the coil or on the end turn of wire furthest away from the reaction winding. The coil is wound with several turns of heavy gauge bare wire and the reaction winding is wound with enamel wire. With the clip on the end turn of wire remote from the reaction wiring, the tuning condenser will cover an approximate wavelength range of 30–60 metres; with the clip on the middle turn of bare wire the wavelength will be approximately 20–30 metres.

Obtaining the Shortest Wavelength

The shortest wavelength will be obtained with the clip on the fourth turn from the reaction winding and the wavelength will be approximately 16 metres.

Aerial Socket Clip

The clip which is connected to the aerial socket at the back of the cabinet is usually joined to the third turn of bare wire nearest the reaction winding but under certain conditions it may be necessary to move this clip up or down a turn as explained further on in the paragraph dealing with the general adjustment of the converter.

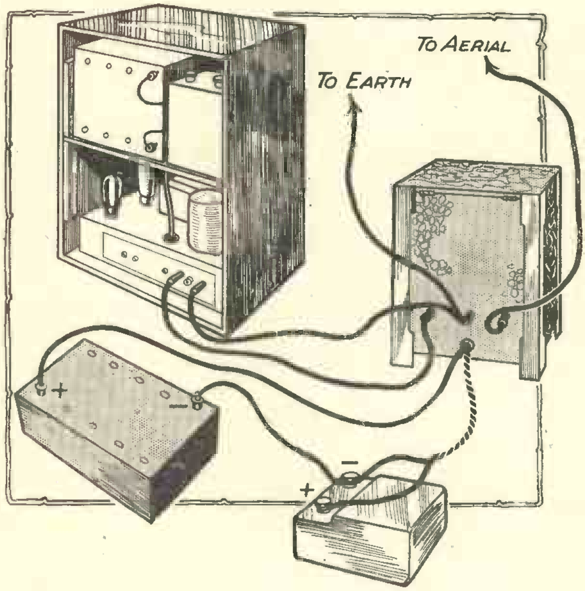


Fig. 2.—Using the Converter with a Battery Set.
Here the converter is shown connected to a battery set, but separate batteries are being used for the converter.

Tuning is very Sharp.

Now a very common fault with the majority of inexperienced listeners is that they will tune a short wave unit as if they were driving a motor bus; they career round the dial expecting stations to roar in and then promptly drop on you, complaining of no results. It is essential to realise that very high frequencies are being dealt with, and it is advisable to try and think of short wave reception in terms of frequency rather than wavelength. As you probably know, the lower the wavelength the higher the frequency. We can quite easily accommodate three strong broadcast signals within a space of four or five degrees on the tuning dial without any interference one from the other.

HOW THE CONVERTER WORKS

At this point the reader will no doubt be asking how the converter works. Briefly, its operation is as follows: We must aim at changing a wavelength, say of 30 metres, to a wavelength for example of 1,100 metres. What does this imply? We immediately think, and quite correctly, of the super-heterodyne circuit, and this is the principle on which the "Eelex" converter works.

Converting the High Frequency Signal

In converting the high frequency signal we are receiving to the long waves, we must, of course, choose a wavelength which is free from an interfering signal. A search round wavelengths between 1,000 and 2,000 metres quickly reveals the presence of a considerable number of broadcast stations and, unfortunately, a large quantity of portable field stations under the control of the Air Ministry, besides automatic lighthouses. However, the choice of a silent spot is not so difficult as would appear at first sight and an approximate wavelength of 1,100 metres is generally quite clear. The effect of settling on a position on which a long wave station may be working would mean that this station would filter through the short wave converter, actually filtering through the capacity of the valve to the broadcast set.

The Super-heterodyne Principle

Now in the standard super-heterodyne receiver, we have our first detector valve followed by two, three or more stages of H.F. amplification or as is usually termed, intermediate frequency amplification, followed by our second detector, finishing off with a low frequency amplifier which can be any standard coupling. Coming back again to the first detector, there is, of course, the oscillator. Circuit arrangements permit either a separate valve being used as the oscillator or the first detector can be used as a combined detector and oscillator. It is on the latter principle that the "Eelex" short-wave converter works.

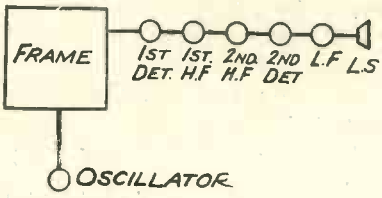


Fig. 3.—Diagram showing principle of Operation.

The Principle of Operation Explained

The principle of operation may be more readily followed with the aid of Fig. 3. We have joined to the first valve which may be an anode-bend detector, the frame aerial and also a coupling coil from the oscillator. The frame aerial, of course, tunes to the stations we want. Next come two stages of long wave amplification. What we do is first to collect the desired signal in the frame aerial circuit and to turn this signal into a long wave one, which in this instance is 1,100 metres. Then we magnify the signal at this wavelength and detect it again. The output is then taken to the power valve in the usual way.

Adjusting the Frequency Changer

We therefore, have briefly, a frequency changer at the beginning of the set and a long wave amplifier followed by a detector and power stage. An obvious advantage is the great magnification to be obtained on the long wavelength with complete stability. In the standard super-heterodyne circuit, the long wave amplifier is usually fixed. All we have to do to tune is to adjust the frequency changer. You tune the frame aerial to the station desired say on 300 metres or a frequency of 1,000,000 cycles, next adjust the oscillator to beat with this frequency and produce a new frequency of 110 k.c. the frequency of the long wave amplifier.

Cumulative Grid Rectification

Thus the oscillator can be tuned to 1,000,000 cycles plus or minus 110 k.c. Now in the grid circuit in the first valve which is working as an anode-bend detector, we have the two signals, the broadcast received and oscillations from the oscillator. These together are rectified and in the anode circuit we have a signal of 110 k.c. This is magnified by the long wave amplifier, rectified by the second detector which in this case is cumulative grid rectification and passed on to the power valve.

In the anode circuit of the first detector are currents of other frequencies besides those of 110 k.c., but these are shunted away by the first circuit. The process of tuning is, therefore, one of adjusting the frame aerial circuit to the wavelength of the station desired and of adjusting the oscillator to provide the beat frequency. Actually, you tune the oscillator to two points where the necessary long wave signal is produced, one oscillator frequency being above that of the station and the other below.

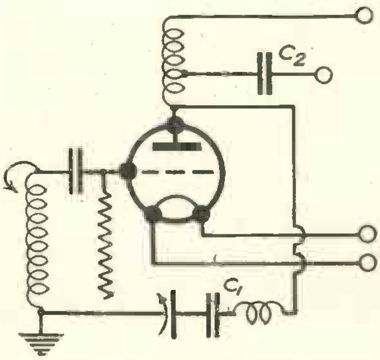


Fig. 4.—How the Super-Heterodyne Principle is applied to the Short Wave Converter.

How the Principle is applied to the Short Wave Converter

In the short wave converter the first detector and oscillator is combined, the one valve doing the work of two.

The frame aerial has now, of course, been replaced by the tuned circuit of the converter. The output of this converter is coupled to the first high frequency or as you may prefer it, intermediate frequency amplifier (Fig. 4).

CONNECTING UP THE BATTERY CONVERTER

In the battery model converter the circuit is arranged in such a manner that it is possible to utilise the existing batteries on a broadcast set. No negative high tension connection is provided for. The reason for this is, of course, quite obvious when we realise that the negative connection is already made in the earth return circuit of the broadcast receiver. If this unit was to be used in conjunction with a mains receiver, however, it would, of course, require its own separate batteries and in this case, an extra connection would have to be taken from the negative end of the high tension battery to the negative of the L.T. supply.

Fig. 5.—USING THE CONVERTER WITH AN A.C. MAINS SET.
Here the high tension supply is being obtained from the screened-grid valve.

Fig. 6.—USING THE CONVERTER WITH AN A.C. MAINS SET.
Showing the H.T. supply being obtained from side terminal of pentode valve.

Aerial, Earth and Output

Disconnect the aerial from the broadcast receiver and connect it to the socket on the unit marked "Aerial". Leave the earth connection connected to the earth terminal of the broadcast set, but take another wire from this earth terminal and join it to the "Earth" socket on the short wave unit. Finally, join another short piece of wire from the aerial terminal of the broadcast receiver to the socket on the converter, marked "Output."

Bad Earths may cause Hand Capacity

It is essential to use a good earth connection with this unit, in order to avoid any slight trace of hand capacity. The earth is more important than the aerial and any good indoor or small outdoor aerial will be quite suitable for short wave reception. Even a fairly long aerial will not be detrimental, but in this case it may be necessary to work with the clip connected to the aerial on the first or second turn of wire.

The earth lead should be as short as possible and should consist of some fairly thick wire joined either direct to ground or to a main water-pipe; gaspipes should be avoided. If these conditions are observed, there will be no trace of hand capacity at all.

Fig. 7.—USING THE CONVERTER WITH AN A.C. MAINS SET.

Here pin P of the valve adaptor has been removed prior to connecting the green lead to it, when obtaining H.T. from the pentode valve. The adaptor can be placed either in the detector, first L.F. or output sockets, but not in the screen grid valve holders.

Connecting to the Accumulator

There are three battery leads coming out at the back of the short wave unit. The red and black twisted flex leads should be connected to the red and black terminals, positive and negative on the accumulator. The leads which are already connected to the accumulator from the broadcast receiver are left on. In other words, each terminal of the accumulator now has two connections, a positive and negative lead going to the main set and a second positive and negative lead going to the short wave unit.

Connecting to H.T. Battery

The remaining flex lead which is fitted with a small red wander plug is plugged into a socket on the high tension battery between 80 and 100 volts. This voltage is not critical but in some cases better results may be obtained by slightly increasing the high tension voltage up to 100. This converter can also be used on an A.C. mains H.T. eliminator and the connections to the eliminator are exactly the same as described above.

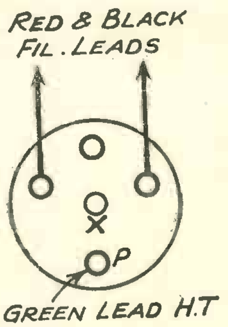


Fig. 8.—AN ALTERNATIVE CONNECTION.

When H.T. is obtained from point X, this should only be done in the case of a 5 pin pentode valve with the H.T. going to the centre pin instead of the side terminal.

Using the Converter with a D.C. Mains Set

If the receiver to be used with this converter is designed to work on D.C. mains, it is advisable to use a separate high tension battery with the converter; as the current consumption of the valve in the unit is extremely low, the life of the high tension battery would be between nine and twelve months. A suitable size accumulator for use with the short wave unit is the Exide type D.T.G., price 4*s.* 6*d.* This accumulator will give approximately seventy-five hours use on one charge.

Valve to Use

As the short wave converter employs a super-heterodyne circuit, it is necessary to use a separate valve in the unit which acts as a combined detector and oscillator. The type of valve particularly recommended is the Mullard PM2DX, as alternatives, the Mazda L.210 or Mullard PM1LF will give excellent results. For 4 and 6 volt valves, the Mullard PM4DX and PM6 D respectively, should be used.

CONNECTING UP THE MAINS CONVERTER

This unit is supplied with a special 5-pin plug adaptor to which is attached a twisted red and black flex. This adaptor should be plugged into the detector valve holder or first L.F. valve holder (if any) or the output valve socket

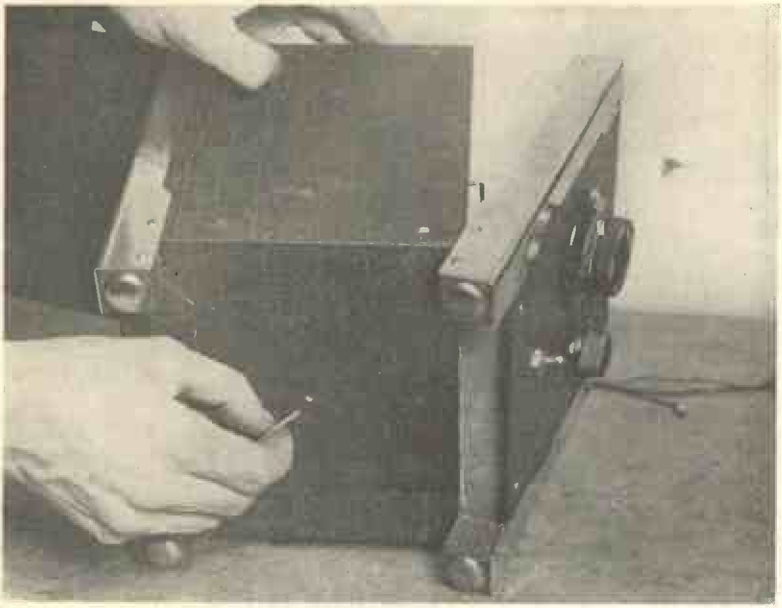


Fig. 9.—DISMANTLING THE "EELEX" SHORT-WAVE CONVERTER.

The screw underneath the baseboard should be removed, together with the wood screws which hold the front corner brackets of the cabinet.

What to do when a 5-pin Pentode Valve is used.

An alternative connection is to point X (Fig. 8), and here again care being taken to see that the tag does not touch the other pins. If the lead is connected to this last point, it should only be done in cases where a 5-pin pentode valve is used, with the H.T. going to the centre pin instead of the side terminal. The Mazda A.C./PEN valve has the H.T. terminal at the side whereas the majority of other pentode valves have the H.T. connection in the centre of the base.

of the broadcast receiver. The valve is then replaced on top of the adaptor. This connection supplies the low tension voltage to the short wave unit.

High Tension Voltage Supply

The green flex lead supplies the high tension voltage for the converter and its method of connection depends on the type of broadcast receiver in use. Various connections suggested below should be tried to see which gives the best results. If a pentode valve is used, which has a side terminal connected to the H.T. supply, the green lead can be connected to this or it can be connected in the following manner:

Remove the pin P of the valve adaptor and join the green lead to this point by replacing the valve pin. Care should be taken to tighten up this pin with a small pair of pliers in order to avoid any possibility of the tag touching the other pins. The adaptor can now be placed either in the detector, first L.F. or output sockets, but should not be placed in the screened-grid valve holders.

Connecting to Anode Terminal of a Screened-Grid Valve

An alternative connection can be made to the top (anode) terminal of one of the screened-grid valves.

Valve to Use

For the A.C. mains unit the type of valve particularly recommended is the Marconi-Osram MHL4. As alternatives the Mazda AC/HL or Mullard 354V will give excellent results.

USING THE CONVERTERS

The holder for the oscillator valve will be found at the side of the coil base. First of all place the clip, which is connected to the aerial socket at the back of the cabinet, on the third turn of bare wire nearest the enamel reaction winding, and the second clip, connected to the variable tuning condenser, on the last turn of wire on the left-hand side of the unit.

Fig. 10.—OPENING THE PINS OF THE COIL.

This can be done with a penknife as shown. The pins should be occasionally cleaned and opened in order to ensure a tight fit.

Switching on the Set

Switch on the main receiver and tune it to approximately 1,100 metres, as previously explained. Switch on the short wave unit by means of the filament switch on the front panel. The small knob on the right of the tuning dial is the reaction control.

Tuning the Converter

Adjust the reaction control on the broadcast set until it is just off the point of oscillation (if reaction is employed in the receiver); then slowly turn in a clockwise direction the reaction on the converter until the short wave unit is heard to go into a mild state of oscillation. This will be made apparent by a slight hissing noise in the loud speaker. The object of this reaction control is to keep the oscillator in a continuous state of oscillation.

What to do if the Converter fails to Oscillate.

If it is found that on a certain part of the tuning scale the reaction control fails to make the unit oscillate, this may be due to the clip, which is connected to the aerial, being too far up the coil, in which case it should be moved a turn nearer the reaction winding.

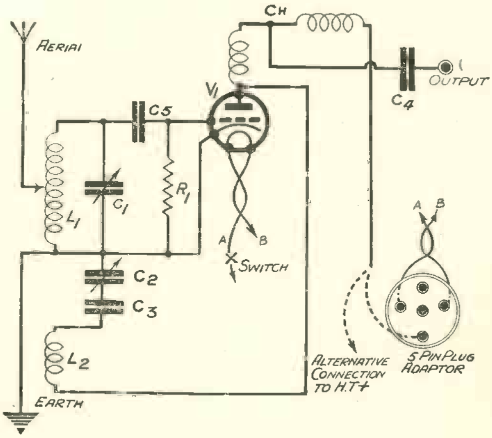


Fig. 11.—CIRCUIT DIAGRAM OF THE "EELEX" SHORT WAVE CONVERTER.

C_1 = ·0002 mfd. s/m variable condenser.
C_2 = ·0001 mfd. reaction.
C_3 and C_4 = ·001 mfd.
C_5 = ·0001 mfd.
L_1 and L_2 = "Eelex" short wave coil.
R_1 = 2 megohm grid leak.
V_1 = MHL4 valve.
CH = "Eelex" Duplex H.F. choke.

A Point about Reaction

In some circumstances an effect may be noticed where the reaction is increased as the wavelength is increased, which is quite normal, but a point may be reached where it will be found that on continuing the increase in wavelength it is necessary gradually to *decrease* the reaction control. This "peak" is noticed by the converter going into a

Fig. 12.—How to Test whether the Choke is Faulty.
This is done by measuring the anode voltage at the anode socket of the valve holder.

state of violent oscillation as explained below.

A little practice will show that results in some cases may be better with the aerial clip on the first or second turn and in other cases on the third or even fourth turns. The clip should be tried in the various positions to see which gives the best results. Another cause of the unit failing to oscillate sufficiently, may be that the valve is not up to standard and is failing to give its full emission.

What to do if Oscillation is too violent

Should the converter, however, suddenly burst into violent oscillation (an effect which becomes apparent by a loud squeal in the loud speaker), this can be cured either by moving the aerial clip further away from the reaction winding or reducing the high tension voltage.

Fine Tuning Adjustment

The reaction control on the broadcast receiver is now used in the normal way, whilst tuning is carried out by the tuning condenser on the short wave unit, the reaction control on this unit requiring only an occasional touch to keep the converter oscillating. When a station has been tuned in, it will generallly be found that a fine tuning adjustment can be effected by slightly moving the tuning condenser on the main receiver.

An Important Point to remember

Bear in mind when searching for stations that the tuning of the ultra short waves is extremely sharp and it is quite possible to have three powerful broadcast stations within three degrees of the scale without any signs of interference from each other and the tuning should be carried out very slowly. If the condenser is turned too fast, it is easily possible to pass over many powerful broadcast signals without noticing them.

Two Dial Readings for each Station

It will be observed when tuning stations that they are received in two places on the dial, within five to ten degrees of one another. This is an effect generally referred to as second channel reception, and although at first sight this may appear a disadvantage it may be found that at times when a station is subject to interference on its fundamental wavelength, it may be received quite clear of the interference on the second reading.

FAILURE TO OBTAIN GOOD RESULTS PROBABLE CAUSES AND CURES

There is very little to go wrong in the battery and mains short wave converter. Electrical breakdowns occur at times in the best sets and it is possible that at some time or other, a fixed condenser may break down in the short wave unit. With present-day condensers, this break down is very rare, due to the extreme care taken in the manufacture of the components and the quality of the material used.

The Grid Condenser

It is extremely doubtful if the grid condenser or grid leak will ever give any trouble and these will certainly not break down due to high voltage pressure as there is no high voltage from the power supply developed across them.

The Two ·001 Mfd. Fixed Condenser

The two ·001 mfd. fixed condensers do, however, carry the strain of the H.T. supply. The fixed condenser, c^1, which is in series with the reaction condenser is merely inserted in the circuit to act as a protection against an accidental short circuit in the variable reaction condenser. The remaining ·001 mfd. fixed condenser, c^2, is in the output lead of the converter to the input in the broadcast set. This again has the pressure of the anode voltage on one side.

Symptoms of a Faulty Condenser

If reaction control is normal and the symptoms are that the unit is choked up and mushy, with very weak signals in the background it can very usually be taken for granted that one of the condensers has broken down. A further proof of this can be obtained by measuring the anode voltage at the anode socket of the valve holder.

How to tell whether the H.F. Choke is O.K.

If the high tension is arriving at this point, this is proof that the H.F. choke is quite O.K. If no anode voltage should be arriving at the valve holder, however, but is arriving at the H.T. side of the H.F. choke, it is obvious that the choke has broken down.

Dismantling the Converter

Due to the design of the converter, replacement of any component is extremely easy. A screw underneath the cabinet, holding the baseboard, should be removed together with the wood screws which hold the front corner brackets of the cabinet. The unit is then removable, enabling the mechanic to make a close examination of the interior and the underneath of the coil base.

Keep Valve Pins clean

Trouble will sometimes occur through dirty valve pins or dirt or grease on the pins of the coil. These pins should occasionally be cleaned and opened with a penknife in order to make a tight fit. Grating noises when tuning is usually proof of a short-circuiting variable condenser in which case this should be adjusted or replaced.

It is essential that the capacity of this condenser shall not exceed ·00025 mfd. maximum. Weak signals accompanied by a faint background of low-pitched hum will sometimes prove due to a faulty grid leak. This grid leak is underneath the coil base and can be easily replaced. The resistance of the leak is 2 megohms.

COILS AND COIL WINDING

By EDWARD W. HOBBS

A COIL in wireless work is a length of insulated wire wound around a support or "former" of some kind.

Coils of various kinds can be wound by the home constructor and can be paired, matched, or ganged as required to suit the particular purpose in view.

Fig. 1.—A Completed Coil with Wavechange Switch ready for Mounting on the Panel of a Set.

Full instructions for winding such a coil are given in Figs. 21 to 27.

Simple Cylindrical Coil

The simplest form of tuning coil (Fig. 1A) consists of a cardboard tube with the wire wound around the outside.

To wind such a coil, make two small holes near to each end of the tube or "former," then insert the end of the wire through the first hole, bring it out through the second hole and take it in again through the first hole and draw it tight. Leave sufficient wire to all of subsequent connections to terminals on a baseboard, say 6 to 12 inches of wire as an average.

Hold the former in the left hand and wind the wire around the former with the right hand as shown in Fig. 3. The wire should have been obtained coiled on a spool or reel—similarly to a reel of cotton.

At the termination of the winding, fasten off the wire by fixing it into holes as at the start.

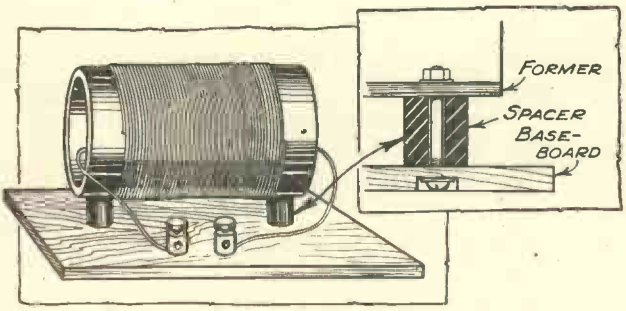


Fig. 1A.—Simple Cylindrical Coil.

A plain winding around a cardboard tube fastened to a baseboard by screws and spacer washers.

Determining Sizes of Coils

To be of practical value a coil must be suitably proportioned to the work it has to do, hence it is imperative that the needful particulars be given, or can be calculated by the winder.

Assuming the coil is wanted as a tuning inductance, it is necessary to know, firstly, the maximum wavelength to which it is to be tuned, and secondly, the value in microfarads of the tuning condenser to be used with it.

As the theory of coils and tuning circuits is dealt with in another section of "Complete Wireless" it suffices to mention here that the normal tuning circuit consists of a coil or inductance (L) in parallel with a capacity (C) in the form of a variable condenser.

Multiplying L by C gives a figure corre-

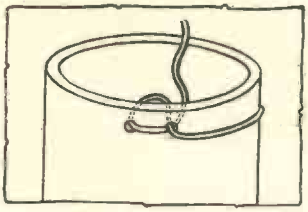


Fig. 2.—FASTENING THE WIRE.

The start and finish of the windings are fastened to the former by looping the wire through holes, as here shown, and drawing in tight.

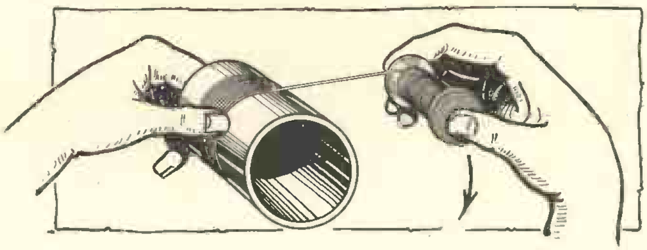


Fig. 3.—WINDING A SIMPLE COIL.

The former is held in the left hand while the wire is wound around the former with the right hand.

sponding to the frequency or wavelength. Conversely, if the value of capacity is known, dividing the LC value by C gives the inductance value, and from this the most practical number of turns of wire for any given conditions can be computed.

The following table gives the LC values for representative wavelengths, others can be obtained by interpolation.

Frequency and LC Values

Frequency Kilocycles per Sec.	Wavelength. Metres.	LC Value.
25,000	12	0·0000407
10,000	30	0·000255
5,000	60	0·00101
3,000	100	0·00281
1,200	250	0·0176
1,000	300	0·0253
800	375	0·0396
600	500	0·0704
400	750	0·1580
300	1,000	0·2810
200	1,500	0·6330
100	3,000	2·5300

The LC value in this table is the value of inductance in micro-henries and the capacity in micro-farads.

Use of the Table

Suppose it is desired to wind a coil to tune up to 500 metres, with a ·0005 tuning condenser.

Opposite 500 metres in the table read the LC value 0·0704.

Dividing this by ·0005 gives 141 mh, which is the inductance value for the coil ; the required number of turns of wire can be calculated from Prof. Nagaoka's formula,

which is $L = 9{\cdot}8\, d^2 n^2 l\, K$,

where L = inductance in centimetres
d = diameter of coil in cms.
n = number of turns per cm.
l = length of winding in cms.
K = correction factor, determined by the ratio of diameter to length of winding.

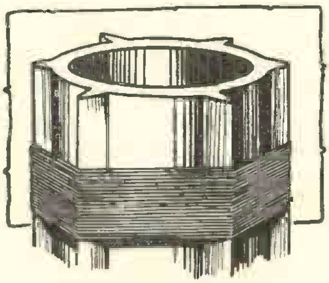


Fig. 4.—MULTI-RIBBED FORMER.

The ribs hold the wires away from the body of the former, and this reduces self-capacity losses.

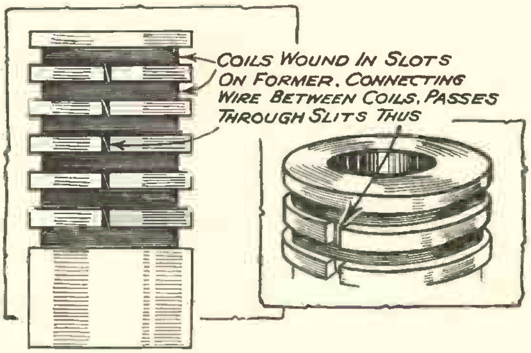


Fig. 5.—SECTIONED SLOTTED WINDING.

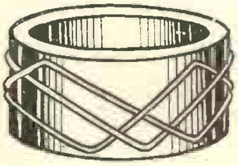


Fig. 6.—IGRANIC HONEYCOMB WINDINGS.

A well-known and highly efficient winding for plug-in and other coils. Three complete turns only are shown.

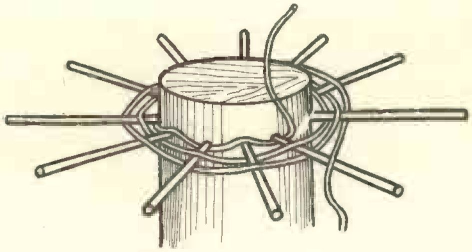


Fig. 7.—BASKET COIL.

This flat winding is wound on a pegged former, the spokes being removed when the coil is complete.

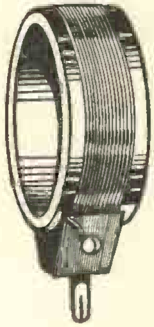


Fig. 8.—PLUG-IN COIL.

Table of Values of K

Diameter in cms.	Length in cms.	K.
10	1	0·200
5	1	0·320
4	1	0·365
3	1	0·429
2½	1	0·472
2	1	0·506
1½	1	0·595
1	1	0·688
1	1½	0·747
1	2	0·818
1	3	0·873
1	4	0·902
1	5	0·920
1	10	0·959

If the design limits the diameter or length of the coil, fill in these dimensions in the formula, thus leaving only the number of turns as the unknown factor. For example, assuming a diameter of 6 cm. length of 2·5 cm. and inductance value of 141 mh.

Convert micro-henries to centimetres by multiplying by 1,000 thus:

$$L = 141{,}000 \text{ cm.} = 9{\cdot}8 \times 36 \times x \times 2{\cdot}5 \times 0{\cdot}47$$

$$\therefore \sqrt{340{\cdot}5}$$

or approximately 19 turns per cm.

A Useful Table

To save some calculation, refer to the following table as a guide to the initial choice of dimensions, then check by the formula given above and make any necessary changes.

Wavelength of Single Layer Coils wound with No. 26 Single Silk-covered Wire or Enamelled Wire.

No. of Turns.	Length of Winding. Ins.	Diam. 2 inches.	Diam. 2½ inches.	Diam. 3 inches.	Diam. 4 inches.
20	0·36	185	205	220	255
30	0·54	240	270	295	350
40	0·72	285	330	370	440
50	0·9	335	385	435	530
60	1·8	370	430	495	610
70	1·25	415	480	550	680
80	1·5	450	525	605	750
90	1·62	490	575	655	820
100	1·8	525	615	710	885
120	2·2	590	700	805	1,000
140	2·5	650	770	895	1,125
160	2·9	705	840	970	1,225
180	3·2	755	905	1,060	1,340
200	3·6	805	970	1,130	1,440
220	4·0	855	1,025	1,200	1,535
240	4·3	895	1,080	1,270	1,625
260	4·7	940	1,130	1,330	1,710
280	5·0	990	1,180	1,390	1,790
300	5·4	1,025	1,235	1,450	1,870
340	6·1	1,100	1,330	1,560	2,030
380	6·9	1,140	1,410	1,670	2,170

Note.—When tuned with a ·0005 condenser in parallel the wavelength is increased by approximately 50 per cent.

These figures are based on the use of a normal outdoor aerial, but neglecting the effect of a tuning condenser, the maximum wavelength will be increased if the condenser is in parallel across the inductance but will be reduced if it is in series.

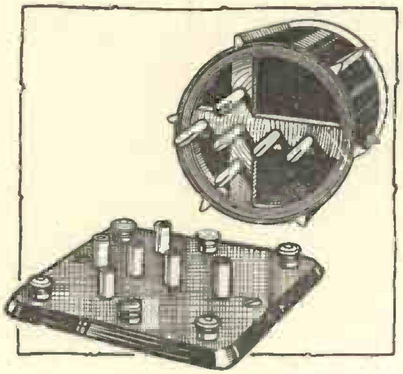


Fig. 9.—6-PIN FORMER AND BASE.

A coil former with six contact pins which fit into sockets in the base.

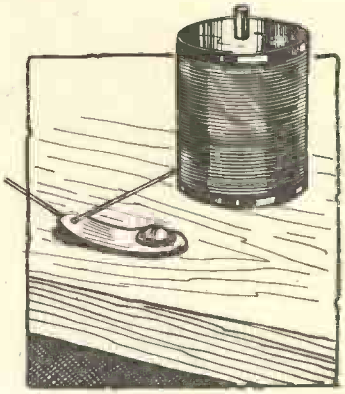


Fig. 10.—LEATHER GUIDE FOR WIRE.

When winding by hand, mount the spool of wire on a spindle and lead the wire through a hole in a piece of leather fixed to the work-bench.

The table, for example, shows that a coil 2½ inches diameter, 1 inch long wound with 50 turns of No. 26 S.S.G. wire has a maximum natural wavelength of 385 metres when used alone.

Checking the Suitability of the Coil

To check the suitability of this coil for tuning to 500 metres with a ·0005 condenser; substitute values in the formula and convert the inches to centimetres, thus $L = 9{\cdot}8 \times 36 \times 361 \times 2{\cdot}5 \times 0{\cdot}47 = 150{\cdot}648$ cms. $\therefore L = 150{\cdot}6$ microhenries, and multiplying by the capacity of the condenser, that is ·0005 m.f. gives ·0753 as the LC value, which by reference to the Table on p. 382 is seen to be rather more than adequate.

This comparatively simple formula gives practical results, but variations in either direction may be found in practice and may be due to other factors, including the quality of workmanship.

The number of turns of wire that can be wound on a coil of any diameter, per 1 inch, or per 1 centimetre of length, can be read directly from the following table.

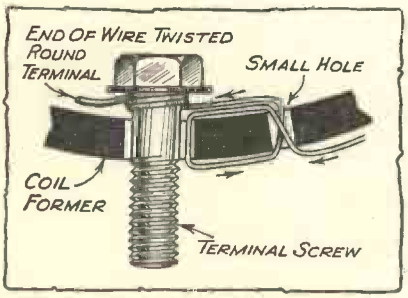


Fig. 11.—FASTENING WINDING TO TERMINAL.

The wire passes in through a small hole around the back, out through the terminal hole, then into the first hole, and is turned around the terminal. The tube is shown broken away.

Table of Turns and Wire Gauges.
Number of Turns per inch and per centimetre.

S.W.G.	Turns per inch.			Turns per Centimetre.		
	Enamelled.	S.S.C.	D.S.C.	Enamelled.	S.S.C.	D.S.C.
18	20	20	19	7·8	7·8	7·3
20	26	26	25	10	10	9·9
22	33	33	31	13	13	12·4
24	42	42	40	16·5	16·4	15·5
26	50	50	47	19·5	19	18·5
28	61	60	56	24·0	23·5	22
30	73	72	67	28·5	28	26
32	83	81	75	32·5	32	29·5
34	98	93	85	38·5	36·5	33·5
36	116	110	102	45·5	43·0	40
38	143	133	121	56	51	47
40	180	159	142	71	62·5	55

Combination of Capacity and Inductance

There are innumerable combinations of values of capacity and inductance which give the same wavelength, but changes in either may affect other constants in the circuit, for example, in the average receiving set, selectivity is increased by the use of a relatively large condenser and small inductance, while greater sensitivity is attained by the use of a maximum inductance and minimum capacity.

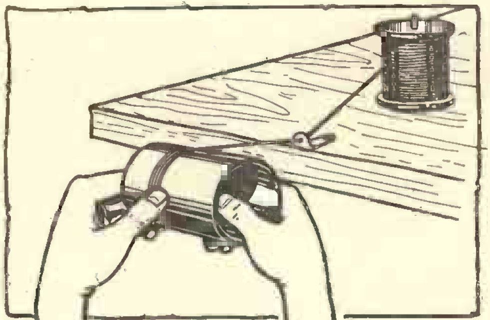


Fig. 12.—Coil Winding by Hand.

Hold the former with both hands, letting the wire draw through the leather guide on the table.

Effect of Size of Coil

The modern tendency is to employ small diameter cylindrical coils wound with fine wire, but this is probably dictated by a desire to produce a compact receiver and to make screening an easier matter. In the case of plain single layer cylindrical coils the proportions for maximum efficiency for a given length of wire should be such that the ratio of diameter to length should be equal to 2·4. Thus a coil 2 inches long should measure 4·8 inches or, say, 4¾ inches diameter. This was enunciated some years ago by Professor Nagaoka and has not yet been disproved.

Effect of Arrangement of Wires

The manner in which the wire is wound has a marked effect on the efficiency; some of the methods that have been tried include, first, the plain cylindrical winding on a solid tubular former, which is improved upon by using a multi-ribbed former such as that in Fig. 4—the windings have less self-capacity because of the air gaps between winding and former.

Sectioned slotted windings as in Fig. 5 are very good, the spacing in sections takes full advantage of the mutual inductance of adjacent coils.

The Igranic honeycomb winding (Fig. 6) has the advantage that self capacity is very low because the wire is so wound in a particular criss-cross manner that virtually separates adjacent turns by a considerable amount.

Another attempt to reduce self-capacity losses was that known as the Basket Weave as shown in Fig. 7, this kind of coil is seldom used nowadays but is easy to make and fairly efficient, the self-capacity being comparatively low.

Slab wound coils are somewhat similar but are wound on a spool. The following are details of average windings and wavelength ranges when tuned with a ·0005 condenser.

Basket Coils		*Slab Coils*	
No. 24 D.C.C. Wire. Former 1 inch diameter.		No. 36 D.S.C. Wire. Former 1¾ inch diameter.	
Turns.	Metres.	Turns.	Metres.
25	175–275	50	300–500
35	200–375	75	400–650
50	275–500	90	500–900
75	400–875	100	600–1,050
100	600–1,000	150	1,050–3,000
150	1,000–2,200	200	1,800–4,000
200	1,500–3,000		

Size of Wire to Use

The best wire for winding coils is first quality high conductivity copper wire suitably insulated either by a silk, cotton, or enamelled covering; in some cases, for instance for short wave reception, it is advantageous to use Litz wire.

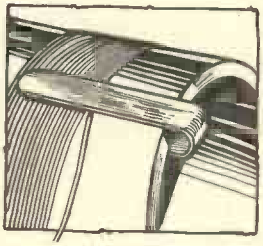


Fig. 13.—Retaining Clip

A springy metal clip is used to hold the winding during a stoppage.

The size or gauge of wire is determined by various factors, including the physical size of the coil itself, the frequencies to which the coil is to be tuned and any factors affecting the effective resistances of the coil.

Actually, the best diameter of wire to use should be settled by the frequency range of the coil, because a high frequency alternating current does not penetrate the wire as a steady D.C. current does, but is distributed over the surface.

Too large a wire is wasteful of material and is unnecessary from an electrical point of view.

On the other hand, too fine a gauge of wire may raise the ohmic resistance unnecessarily when the coil has to pass steady D.C. currents. The penetration depth for straight wires can be calculated fairly closely, and is about 1/100th inch at a frequency of 1,000 k.c.s.

If the wire is to have the same resistance to A.C. as to D.C. currents at, say 1,000 k.c.s., the wire must not exceed about 1/125ths inches or, say, No. 36 S.W.G.

If this straight wire is wound evenly on a cylindrical former the A.C. resistance rises enormously, but the D.C. resistance remains unchanged.

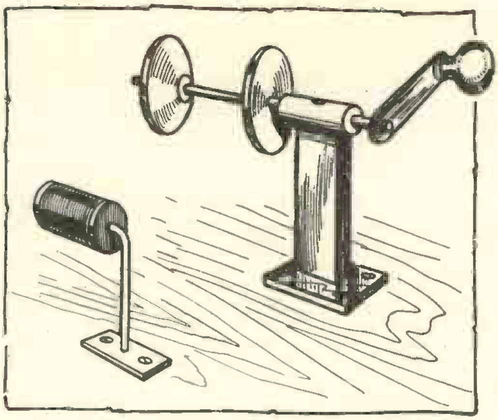


Fig. 14.—Simple Coil Winder.

An arrangement of this kind can be extemporised with wood, or purchased ready for use.

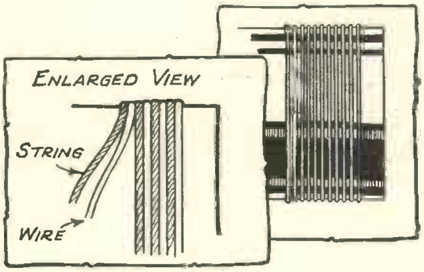


Fig. 15.—Spacing Wires with Thread.

Uniform spacing of wires is attained by simultaneous winding on the wire and a strand of thread—which is subsequently removed.

Low Loss Coils

The term low loss is applied to super-efficient coils, especially those wound with Litz or finely-stranded wire. One practical point to bear in mind is that a low loss coil induces a relatively large field of force, which is no great harm when a single tuning coil is used, but may cause much trouble by interaction with other coils in a multiple tuned circuit.

Adequate screening prevents this interaction but has a damping effect on the coil.

Short Wave Coils

These coils are frequently wound with extra thick wire, or with Litz wire. The details on p. 387 will be found helpful when making plug-in S.W. coils.

The wavelength given is for average aerial and when tuned with ·00025 condenser in parallel.

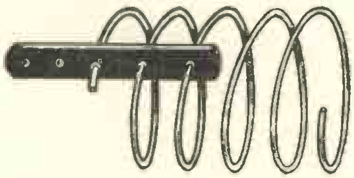


Fig. 16.—Threading Spacers on S.W. Coil.

Ebonite spacers are used to hold the coils in place and prevent relative movement.

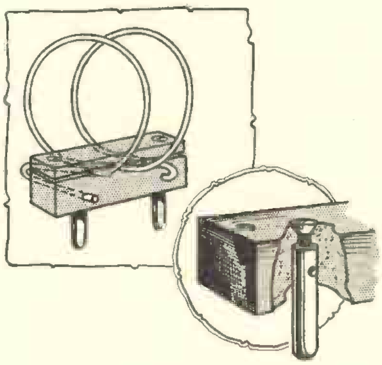


Fig. 17.—Short Wave Coil Mount.

The bare wire coil is spaced by ebonite strips and clamped to an ebonite base.

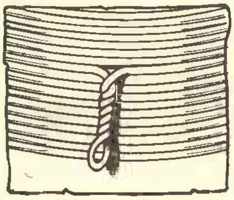


Fig. 18.—LOOP TAPPING.

A loop is formed in the wire, the insulation scraped off, and the loop twisted together.

Short Wave Coils

No. 16 Bare Copper Wire (Tinned).

Diam. Inches.	Turns.	Wavelength. Metres.
1	8	7–15
3	2	15–25
3	4	20–50
3	6	35–75
3	9	45–100

Types and Choice of Formers

Formers for coil winding may consist of plain cardboard tubes, Paxolin tubes, fibre bakelite or ebonite moulded formers and tubes, and specially prepared and built-up formers consisting of rings of insulating material spaced by rods of similar material.

For rough experimental work a cardboard tube or specially shaped built-up former will often suffice, especially if impregnated by immersion in molten paraffin wax.

For maximum efficiency the best material is that with the lowest specific inductive capacity; the following table gives figures for some of the more popular materials.

Air is taken as unity—that is 1·0, hence a material with a specific inductive capacity of, say, 2·25 gives 2¼ times the capacity effect of air as a di-electric.

Specific Inductive Capacity of Di-electric Materials

Paraffin wax	1·8
Waxed cardboard	2·0
India rubber	2·12
Ebonite	2·25
Fibre	2·75
Shellac	3·0
Bakelite	4·0
Glass (light flint)	6·75
Mica	7·75

Ribbed Formers

Specially moulded ebonite formers in the form of a tube with several longitudinal ribs have proved to be highly efficient; the wire is wound over the ribs which hold the wire away from the body of the former; hence self-capacity losses are at a minimum.

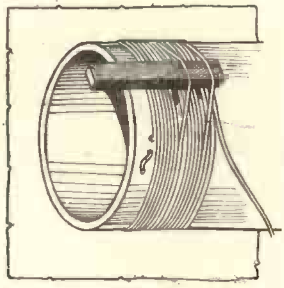


Fig. 19.—JUMP WIRE TAPPING.

Tapping points are formed by taking the wire over an ebonite strip.

Similar formers with contact plates and a separate detachable base with contact plates and terminals are on the market and are most useful to the home constructor.

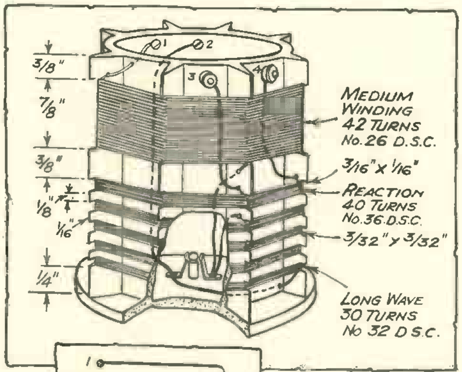
Stock sizes of formers range from 1 to 4 inches diameter and up to 6 inches in length; some small diameters can be had in the solid for use when winding choke coils.

Interchangeable Coil Mounts

Whenever it is desired to cover a considerable wavelength without switching, it is advantageous to have the coils wound on a standard size former having contacts upon it which engage with others on a fixed base.

The original "plug in" coils as shown in Fig. 8, are quite practical. They really consist of a short cylindrical coil attached to an ebonite block having a contact plug and socket to which the ends of the winding are attached.

A development of this form consists of a former with six pins, which engage with sockets in a



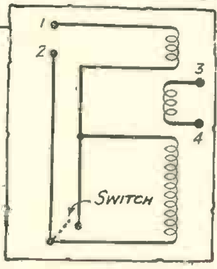


Fig. 20.—GENERAL PURPOSE TUNING COIL.

This coil is adaptable to many popular modern circuits. Here are given the dimensions, structural details and circuit.

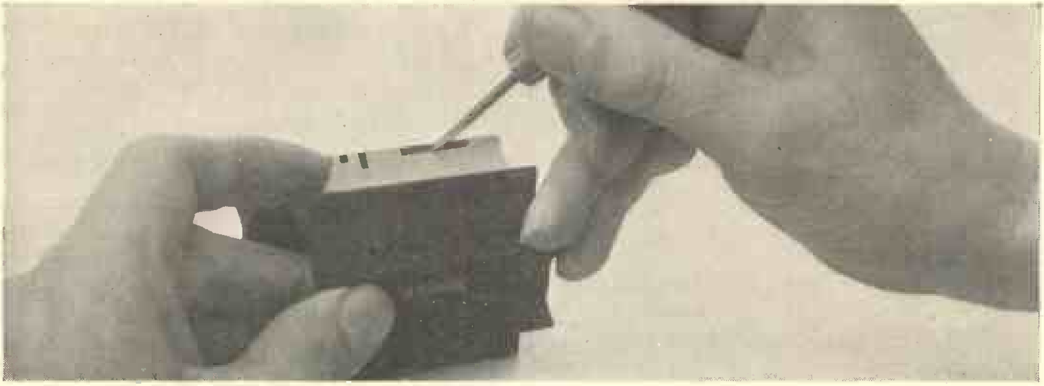


Fig. 21.—Marking Slots on Ribs.

Use a card template while marking the positions of the slots on the ribs with a sharp-pointed scriber.

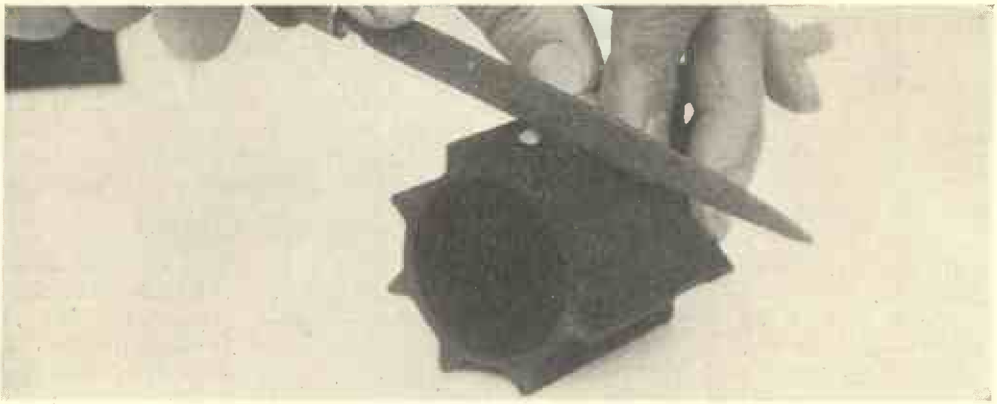


Fig. 22.—Filing the Medium Wave Slots.

Guide the file by means of a piece of wood held against the former to keep the file from slipping and damaging the edges.

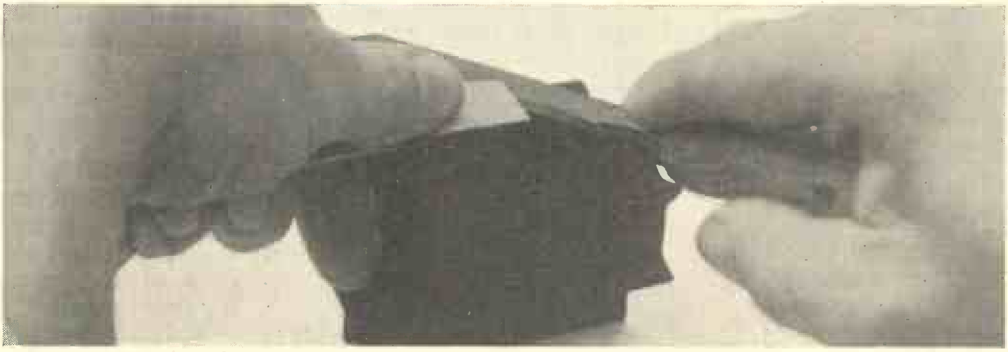


Fig. 23.—Cutting Long Wave Slots.

A flat file is used for cutting the slots for reaction and long wave windings; it is guided by the strip of wood for the first few strokes to get a good start. Hold the former firmly and press it down on the table while filing.

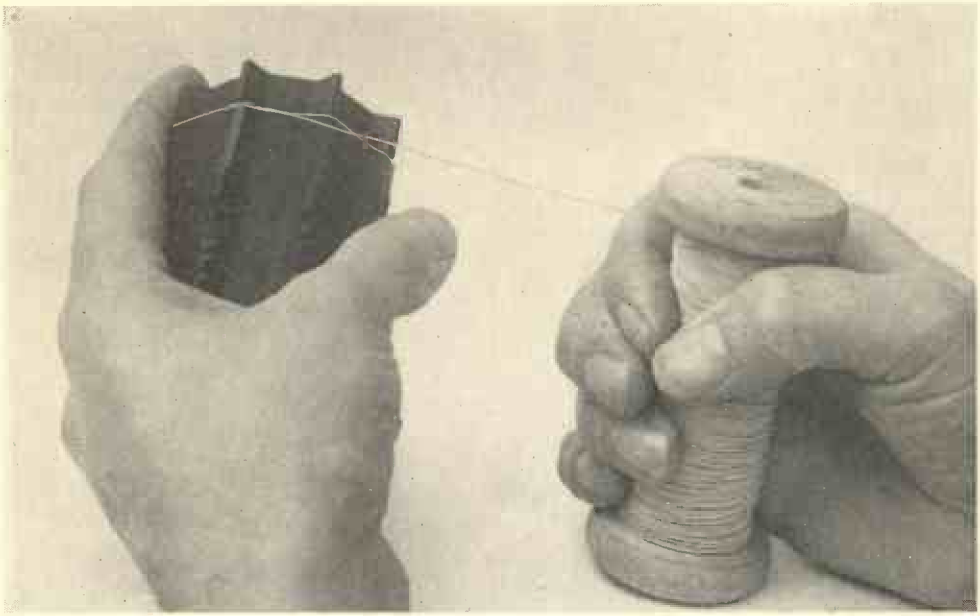


Fig. 24.—COMMENCING THE MEDIUM WAVE WINDING.
Put the end of wire twice through the hole drilled through the rib, then commence winding.

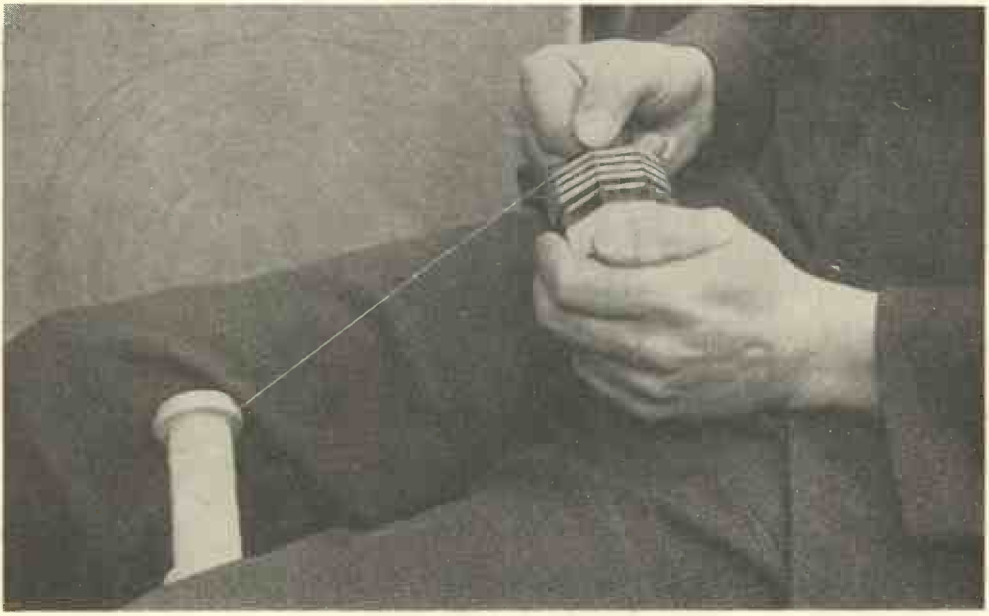


Fig. 25.—COMPLETING THE LONG WAVE WINDING.
The spool of wire should be gripped between the knees while the seated worker rolls the former along under the wire and keeps an even tension on it.

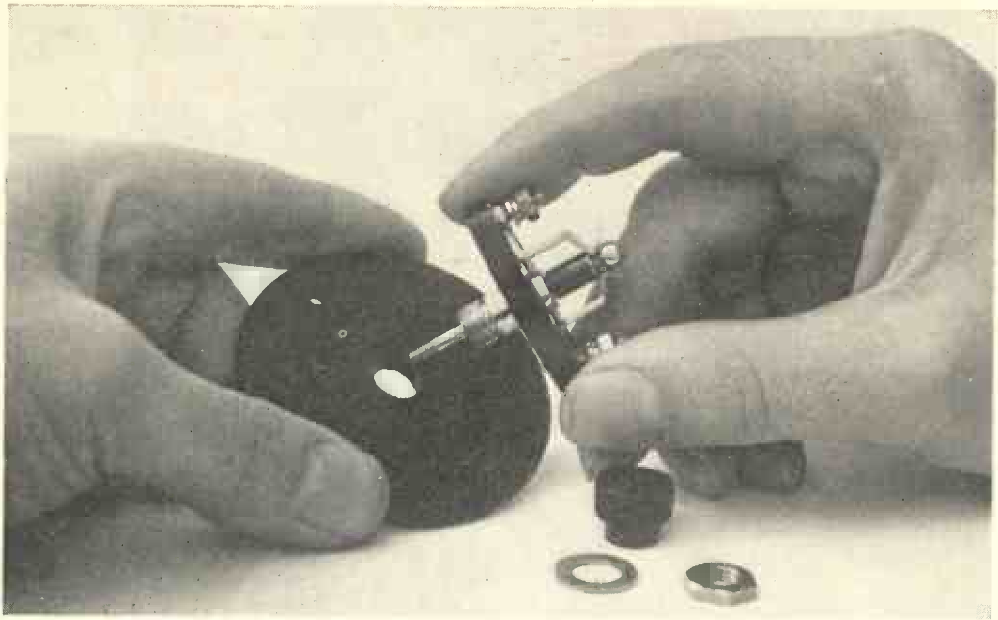


Fig. 26.—FITTING SWITCH TO BASE.

The shorting switch is fixed to the base by a long nut. Note the screws which hold the former to the base.

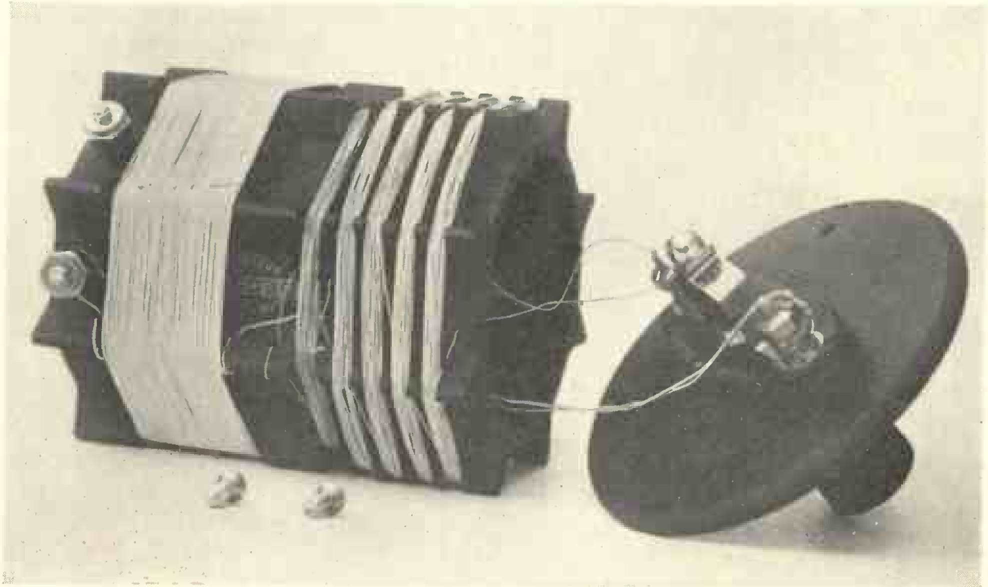


Fig. 27.—INTERNAL CONNECTIONS TO SWITCH.

The end of medium wave winding and start of long wave windings are twisted together and taken to one terminal of the switch. The end of long wave winding is connected to second terminal of switch and taken up to a terminal on the other end of the coil former.

fixed base—as shown in Fig. 9. This arrangement allows of several combinations of windings, the usual arrangement and notation is contacts Nos. 1–2 connect to aerial tuning coil for medium waves, contacts 3 and 4 connect to long wave winding, contacts 5 and 6 to the reaction winding. The lowest number is usually the start of the winding; all windings are in the same direction.

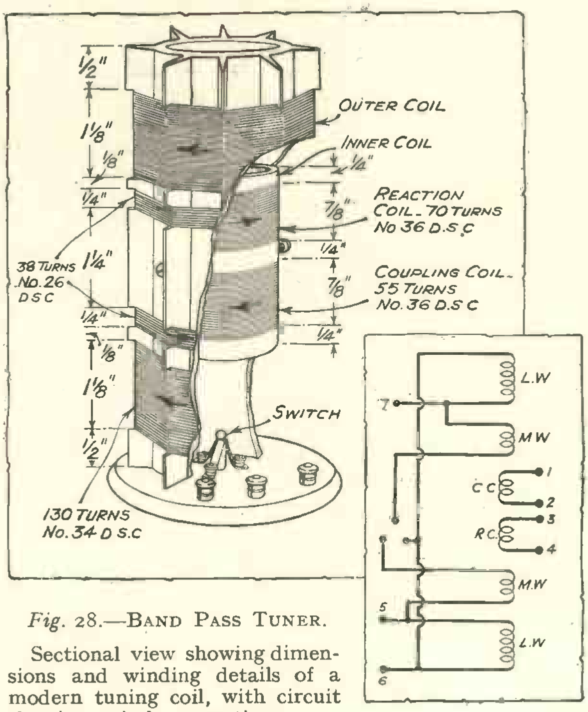


Fig. 28.—Band Pass Tuner.

Sectional view showing dimensions and winding details of a modern tuning coil, with circuit showing switch connections.

COIL WINDING

The following hints cover practically any form of plain cylindrical or ribbed coil winding, the only variations being in the number of turns, gauge of wire and arrangement of separate windings.

Commence by obtaining sufficient wire ready wound on a spool or reel, and the necessary formers, then if winding by hand, proceed as follows:

Set up the spool on a stout spindle such as a strong nail, uncoil a few feet of the wire and pass it through a hole in a piece of leather nailed to the bench—as shown in Fig. 10—the whole being a little towards the right-hand side of the worker.

The purpose of the leather is to keep the wire in check, to enable a slight drag to be brought upon the wire and to enable both hands to be free to manipulate the former.

Fastening the Wire

Fasten off the beginning and finishing ends of the wire, as shown in Fig. 2, by passing it twice through two small holes drilled through the former.

When fastening off to terminals or contacts, as in Fig. 11, drill one small hole through the former and pass the wire twice through it; this relieves the terminal of any pull and minimises risk of breakages.

Take hold of the former with both hands and see that the wire can draw freely from the leather guide on to the top of the former, then rotate the former, keep a steady pull on the wire and see that the first few turns are parallel with the edge of the former.

With a little practice the former can be kept in almost continuous rotation by turning it alternately with each hand, as suggested in Fig. 12, and quite good results can be obtained.

The great things to study are even tension on the wire, and even and regular spacing of the turns.

Endeavour to complete the winding without stopping and do not release the wire without holding it firmly in place, as its elasticity may cause it to spring off the former or cause the turns to slacken.

A letter clip, or a bent piece of springy brass as shown in Fig. 13, should be kept at hand to hold the wire temporarily should a stoppage occur for any reason.

Coil Winding Machine

If many coils are to be wound it is worth while rigging up a coil winding machine—such as that in Fig. 14, either a home-made affair or a ready-made article. The essentials are a stand and bearing for the winding spindle, one end of which has a crank for rotating it, the other is screwed and has a fly-nut. Near to the bearing is a fixed plate, conical in section, and between this and a similar movable plate is fixed the coil former. The spool of wire is mounted on a separate spindle raised and fixed in front of the winder.

In use, the wire is fastened to a rib on the former, or through the tube as the case may be, the former is then rotated by the crank handle and the wire guided into place and fastened off as before.

Short Wave Coils

Coils for reception of the short waves are wound similarly to other coils, but usually a thicker wire is employed and turns are spaced rather wider apart. Figs. 15, 16, and 17 show methods of winding.

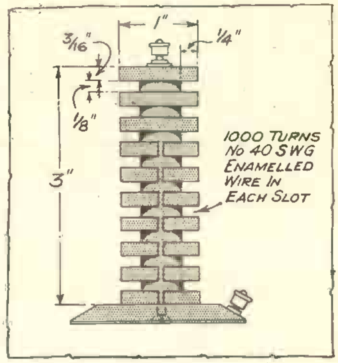


Fig. 29.—HIGH FREQUENCY CHOKE COIL.

Dimensions of a general purpose H.F. choke showing the slots for the windings.

General Purpose Tuning Coil

Dimensions and winding details of a general purpose coil, recommended by the British Ebonite Co., are given in Fig. 20. It can be used either as an aerial or anode tuning coil with or without reaction, a tuned grid coil with reaction or as an HF transformer.

Necessary Materials

The materials required are a No. 12 " Becol " ebonite former, one two-point shorting switch, a circular base, four small terminals and some wire.

Wind first the medium wave winding of 42 turns of No. 26 D.S.C. wire, then put on the 40 turns of No. 36 D.S.C. wire for the reaction coil and finish by winding the long wave winding in four sections of 30 turns, each of No. 32 D.S.C. wire. All must be wound in the same direction ; connections are shown in Fig. 20.

Successive stages in winding this coil are illustrated in Figs. 21–27, and the finished coil is shown in Fig. 1.

Winding a Band Pass Tuner

The arrangement of this tuner and the disposition and number of turns of wire are shown clearly in Fig. 28. There are two medium and two long wave windings on the outer former and a coupling and reaction winding on the inner former.

Necessary Materials

Materials and parts necessary are a No. 9A " Becol " ebonite former $5\frac{1}{4}$ inches long, one " Becol " former $2\frac{1}{2}$ inches long to fit inside the 9A former, one 3-way shorting switch, one 4-inch base, seven small terminals and the wire.

The base is screwed to the former, the switch mounted to the centre of the base and the connections arranged so that the windings are parallel for the medium waves and open-circuited for long waves.

Wind the outer coil first then complete the inner former. Windings are :—

Medium waves, 38 turns, No. 26 D.S.C.
Right-handed turns.
Long waves, 130 turns, No. 34 D.S.C.
Left-handed turns.
Coupling coil, 55 turns, No. 36 D.S.C.
Left-handed turns.
Reaction coil, 70 turns, No. 36 D.S.C.
Right-handed turns.

Matched Dual Range Tuner

A matched dual-range H.F. tuner for use following a screen-grid valve and in conjunction with the above band pass tuner, consists of a former similar to one half of that for the band pass tuner.

The windings are the same, but a coupling coil of 70 turns of 36 D.S.C. is wound on the inner former which measures 2 inches diameter. A two-point shorting switch is used on this tuner.

Winding H.F. Choke Coils

Materials required are a No. 5 " Becol " ebonite former 3 inches long, and a circular base. Dimensions of the coil are given in Fig. 29. For a short wave H.F. choke coil use a No. 5 or No. 4 " Becol " former 1 inch long, with two slots $\frac{1}{4}$ inch deep and $\frac{1}{8}$ inch wide and $\frac{3}{16}$ inch apart. Place 300 turns of No. 36 D.S.C. in each slot.

SEE PAGE 372

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

COMPLETE WIRELESS

A PRACTICAL AND AUTHORITATIVE WORK FOR EVERYONE INTERESTED IN THE WIRELESS INDUSTRY

General Editor :

EDWARD MOLLOY

Advisory Editor :

RALPH STRANGER

VOL. II

Contributors to Vol. II :

SIR AMBROSE FLEMING F.R.S.
F. H. HAYNES
W. R. G. BAKER, Vice-President of RCA Victor Co. Inc.
E. W. HOBBS, A.I.N.A.
HARLEY CARTER
J. A. WHITEHOUSE
F. A. BOYCE
R. HARCOURT WOODALL, A.M.I.E.E.
J. ROBINSON, D.Sc. Ph.D. M.I.E.E.
RALPH STRANGER
W. F. FLOYD, B.Sc. (Lond.)
L. D. MACGREGOR
H. E. J. BUTLER
A. J. HARRIS
A. GOOTNICK
G. H. WATSON
FRANK PRESTON, F.R.A.

GEORGE NEWNES LIMITED
SOUTHAMPTON STREET, LONDON, W.C.2

ii

Index and Classified Key enabling all articles on any particular subject to be readily turned up will be found at the end of the Complete Work.

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD., LONDON AND TONBRIDGE.

PREFACE TO VOL. II

WE have been fortunate in securing as a contributor to this volume Sir J. Ambrose Fleming, F.R.S. Sir Ambrose Fleming was the discoverer of the two-electrode valve from which all other wireless valves have been developed. Had it not been for the research work conducted by Sir Ambrose many years ago it is highly probable that broadcasting would be unknown to-day, and the art of wireless transmission and reception would still be confined to purely commercial purposes. This is a very striking example of how a discovery made by a scientific worker may be the means of starting a flourishing industry and providing a means of livelihood for many thousands of people all over the world. Sir Ambrose Fleming's article, " The Nature and Properties of Wireless Waves," will command the interest and respect of every reader of this work.

Further additions to the series of Servicing articles include the following :—

McMichael.
Burgoyne.
Marconiphone.
Philips.
Columbia.

It has been suggested that these articles will soon become out-of-date, but this is not the case. There are thousands of each make now in use. These have cost their owners anything from £10 to £40 each. Whilst it is not suggested that radio reception has reached such a stage that no further improvements are possible, it can be said that every one of the sets dealt with in this series is capable of giving first-class reception. Therefore, they are not likely to be discarded for several years. When the fortunate owner of, say, a Philips Super Inductance Receiver decides to replace it by a later type, his existing model will, we think, most certainly not be relegated to the scrap heap ; it will be sold or presented to someone else. *These Servicing articles will, therefore, become increasingly valuable for some years,* as it may be assumed that wireless sets, like motor cars, will require more servicing the older they become.

Amongst the wonderful selection of other articles in this volume special mention may be made of " Radio Power Plant," " The Trend of Development in American Radio Reception," " The Superheterodyne," and " The Stenode." As an example of the authoritativeness of the work attention is drawn to the fact that the article on the Stenode has been contributed by Dr. J. Robinson, the inventor of this particular circuit.

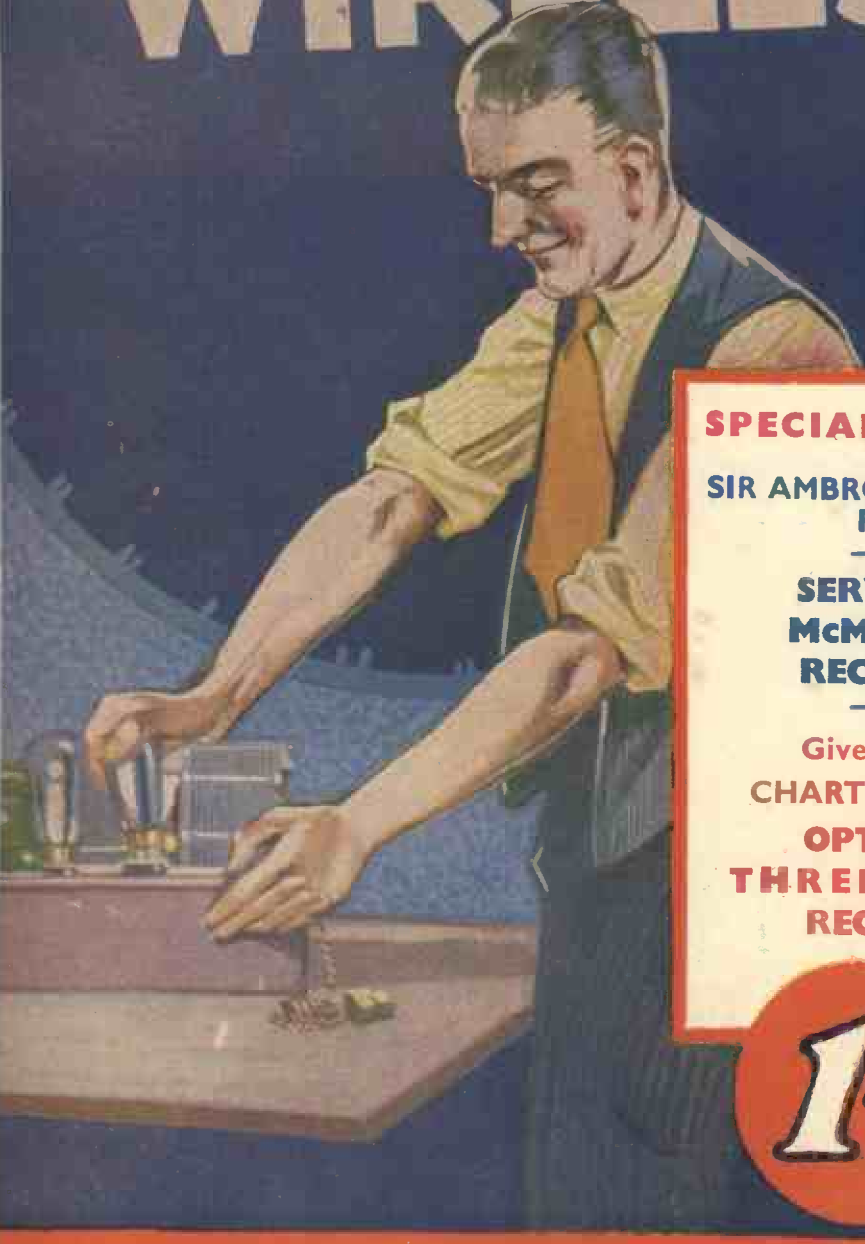
E. M.

iv

CONTENTS

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS



SPECIAL ARTICLE

By

SIR AMBROSE FLEMING, F.R.S.

SERVICING McMICHAEL RECEIVERS

Given Inside

CHART TO MAKE

OPTIMUM THREE VALVE RECEIVER

1/-

Part 9

IN ABOUT 24 WEEKLY PARTS

THE NATURE AND PROPERTIES OF WIRELESS WAVES

By SIR AMBROSE FLEMING, F.R.S.

THE radio amateur and enthusiast who desires to understand the nature of the operations by which wireless wonders are performed must begin by obtaining clear ideas on the subject of electric waves and their nature and properties.

Wave Propagation—and What it Means

The first step is to understand the meaning of the term wave propagation.

When we stand on the seashore on a breezy day and watch the sea waves rolling in it appears to us at first sight as if these long rounded ridges or hummocks of water moved over the surface of the sea. If, however, we fix attention on some floating object, a cork or patch of seaweed, we notice that, as the wave hump passes over it, the floating object is merely lifted up, pushed forward, drawn back and let down, and that this cyclical or periodic motion is repeated as each hump passes. Moreover, if there are two such floating objects we can notice that their cyclical motions are performed successively and not simultaneously. Hence, it follows that each particle of water never moves far from its place of rest and that what travels along is not a material thing but a particular kind of displacement or motion.

In this case we are concerned with so-called surface waves on water, in which the displacement is a surface elevation or depression.

Air or Sound Waves

We can, however, have waves in the body of a material, as in the case of air or sound waves. In this instance the periodic change consists in a compression and expansion of the air at any one point, and this change is repeated periodically at any one place and along the line of propagation.

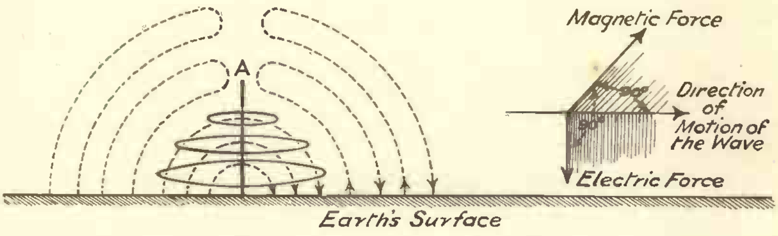


Fig. 1.—ELECTRIC FORCE AND MAGNETIC FORCE.

A is a Marconi aerial wire. The dotted lines represent roughly the form of the lines of electric force, and the firm lines the lines of magnetic force round it. At a distance from the aerial, electric waves are thrown off, in which the electric force is nearly perpendicular to the earth and the magnetic force parallel to the earth near the earth's surface.

Periodic Time and Frequency

When a series of states are being thus propagated the time of one complete cycle of changes at any point is called the *periodic time* and the number of such cycles per second is called the *frequency*. The shortest distance between two points in the line of propagation at which the same states exist at the same time is called the *wavelength*. The ratio of wavelength to periodic time is called the *phase velocity* of the wave.

Three Kinds of Waves

In the case of an elastic solid body we can have propagated through it not only waves of compression, as well as surface waves of elevation, but also waves of distortion due to some kind of twist or rotation of the particles or parts. In the case of earthquake waves we have all these three kinds which are propagated with different phase velocities.

Electric Displacement due to Electric Force

Turning now to electric waves we have some more difficult ideas to grasp. The fundamental notion is that of electric displacement due to an agency called electric force.

Suppose we have a metal ball hung by a dry silk thread. We can give this ball a charge of electricity which may be either positive or negative. In this charged state the ball will attract or repel other charged conductors and it is said to be a source or origin of electric force. This force produces in the space round the ball a state Maxwell called an electric displacement.

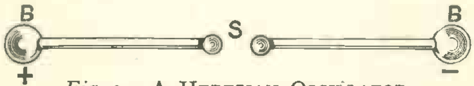


Fig. 2.—A Hertzian Oscillator.

Consisting of a metal rod with two spark balls at the centre and two capacity balls at the outer ends which are charged alternately + and − by an induction coil.

An Error to be Avoided

There is a tendency in the human mind to try always to interpret physical states in terms of motions or positions of substance. This is because such mechanical changes or states are the things we can most easily visualise in our minds. But it is necessary to avoid this error and to accept the idea of electric displacement as a fundamental notion not interpretable in mechanical or motional terms.

Magnetic Flux

Maxwell's next great idea was that whilst electric displacement is changing in amount it produces another state in the surrounding space called magnetic flux, which is at right angles to the line of the displacement in direction. Moreover, any variation or change in the amount of this magnetic flux creates reciprocally an electric displacement.

Just as electric displacement is regarded as an effect due to a cause called electric force, so the magnetic flux is a consequence of magnetic force.

Dielectric Constant and Permeability

The degree to which electric displacement is produced by a given electric force depends on a quality of the space or medium called its dielectric constant, denoted by the letter K. The degree to which magnetic flux is produced by any given magnetic force depends on the permeability of the medium, denoted by the Greek letter μ.

An Experiment with Two Metal Balls

Suppose, then, that we have two metal balls on the ends of a metal rod and that these balls are charged alternately positive and negative, one ball being plus whilst its companion is minus.

Then on a line drawn at right angles to the rod through its centre there will be an alternating electric force at right angles to this line which will be transmitted as a wave motion, because the force due to the charges does not reach distant points instantly, but, as Maxwell showed, with a wave speed equal to the reciprocal of the square root of the product of the dielectric constant and permeability of the medium, viz. to $1/\sqrt{K\mu}$.

At great distances from the balls there is an alternating magnetic flux which is in step with the alternating electric displacement and at right angles to that displacement and to the direction of propagation of the wave. At certain distances, separated by a wavelength, the flux and displacement have maximum values at the same instant along the line of propagation. This wavelength is about equal to double the distance between the centres of the balls on the extremities of the rod.

Hertz's Oscillator

This arrangement is called an oscillator and was first devised by H. Hertz. He

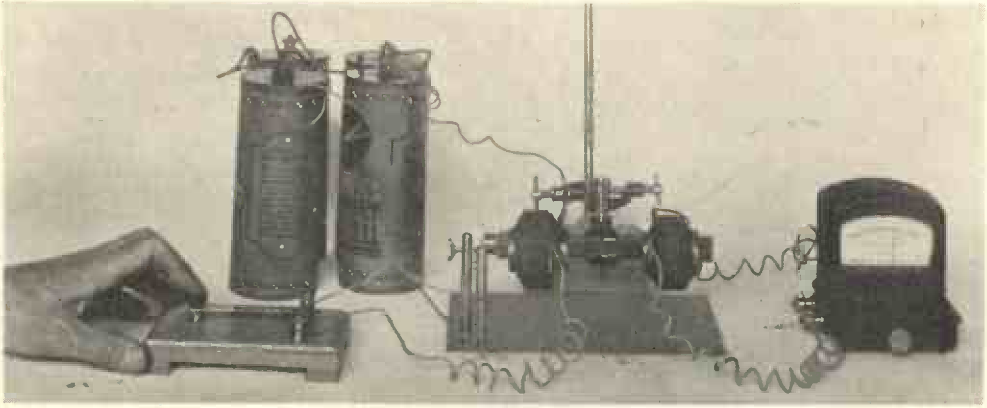


Fig. 3.—THE INDUCTION COIL IN ITS SIMPLEST FORM.

Hertz in his famous experiments employed an induction coil to generate high-frequency oscillations. Here we see the elements of a simple induction coil. The arrangement of the primary and secondary circuits is shown below.

was only able to create short trains of electric waves, a dozen or twenty waves or so, separated by idle intervals, but with our modern thermionic valves we can create continuous, or undamped, electric waves radiated from the oscillator.

It will be seen, then, that by using oscillators of various lengths we have it in our power to create electric waves of different wavelengths which travel through space with the speed of light. In fact, such waves can be now made of wavelengths varying from a small fraction of an inch up to ten miles or so. The very short waves are generally called Hertzian waves, and the longer waves are called wireless waves because they are used in ordinary wireless telegraphy and telephony.

Octaves of Radiation

Now it has been shown by various researches that the radiation we call light, which affects our eyes, also ultra-violet light and the Röntgen or X-rays, are also electromagnetic waves. If we consider the radiation between two limits of wavelength, one twice the length of the other, we call this an octave of radiation. We are now acquainted with sixty or more octaves in all of electric waves, but of this great range only one octave or less affects our eyes as light. Nevertheless, the whole gamut of waves have very similar properties and can be reflected, refracted and dispersed just as can rays of light, and travel through space with the same speed. With respect to wireless telegraphy and

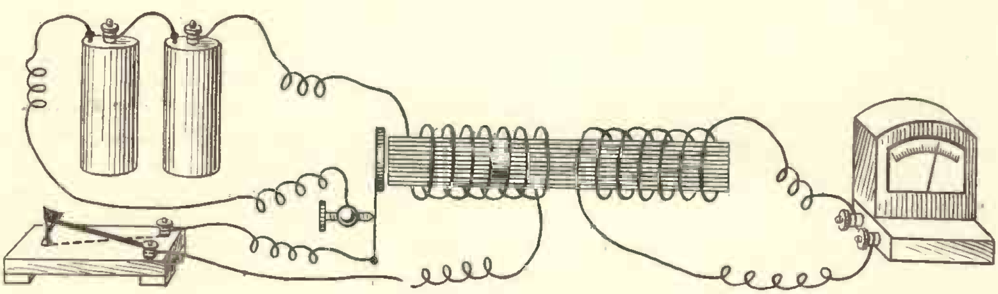


Fig. 4.—THE INDUCTION COIL IN ITS SIMPLEST FORM.

The primary coil is in circuit with a contact breaker or trembler. When the current is switched on, the trembler is attracted to the core and thus breaks the primary circuit. Then it flies back and remakes. These operations take place rapidly in succession, thus generating a high voltage in the secondary.

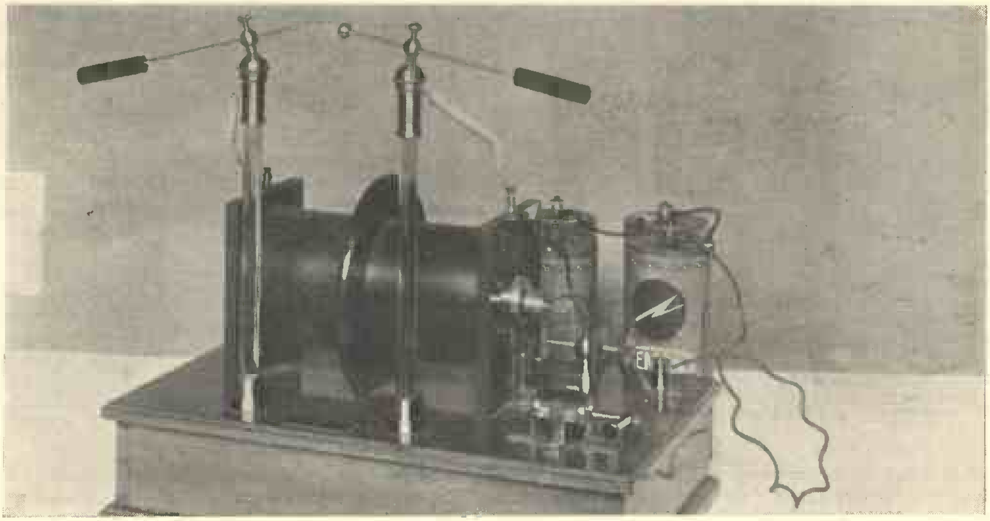


Fig. 5.—A MODERN INDUCTION COIL (*Griffin and Tatlock*).

Using a well-made coil, it is possible to generate many thousands of volts from a low-tension supply of 5 or 6 volts. The primary consists of a few turns of thick wire and the secondary of thousands of turns of fine wire carefully insulated. High-voltage sparks pass between the point and ball terminals and give rise to wireless waves of the type used in the early days of spark wireless telegraphy.

telephony we can say that the range lies between wavelengths of ten miles or so and a few inches, 8 or 10.

Classification of Wavelength

These wavelengths may be roughly classified as follows :—

Long wavelengths	above	3,000	metres
Medium wavelengths		200–3,000	,,
Intermediate ,,		50– 200	,,
Short ,,		10– 50	,,
Ultra short ,,	below	10	,,

There is, however, no sharply marked distinction between the members of the whole range in properties.

The Heaviside Layer

It has now been recognised and proved for many years that the earth's atmosphere above a certain height of very roughly sixty miles is in a state of ionisation. That means that the atoms of the gases of which it is composed have lost electrons and hence become positively electrified, whilst the detached electrons are moving about freely in between. The atmospheric gases are thereby rendered conductors of electricity, and this ionised layer, generally called the Heaviside layer, from an eminent scientist who first drew attention to it, is, as it were, a shell of metal surrounding the earth at a certain and variable height. This ionisation is brought about either by the ultra-violet light in sunlight or else by bombardment of the earth's atmosphere by electrons or ionised particles propelled with great velocity from the sun by the pressure of its light. This Heaviside layer acts as a reflector for certain types of electric wave.

Long Waves and Ultra Short Waves

In the case of the very long waves and of the ultra short ones the propagation is direct ; that is, the long wave reaches the receiver by travelling along the earth's surface, the line of propagation being along a great circle of the sphere.

In the case of the ultra short waves the propagation is along a straight line, or nearly straight line, joining the transmitter and receiver. Hence in this last case there must be no opaque or conducting body intervening in the line of sight. Hence both transmitter and receiver are placed at high elevations so that there is a clear view from one to the other.

Effect of Diffraction

In the case of the long waves the bending round the curvature of the earth is to some extent due to diffraction, which is an effect exactly similar to that which takes place in the case of waves of sound or light. This diffraction only takes place to any considerable effect where the length of the wave is fairly large compared with the size of the object round which it bends. Nevertheless it has been shown that this diffraction is not the sole or chief cause of the bending of long electric waves round the earth.

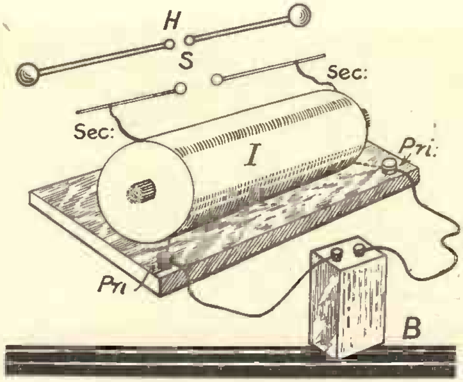


Fig. 6.—Using a Hertzian Oscillator.

The balls are charged by connection to the secondary circuit of an induction coil, I, the primary current being supplied by a battery, B. When a spark passes at the balls, S, electric oscillations take place at H.

Ionic Refraction

The ionised layer in the upper atmosphere acts like a refracting medium and bends the electric rays. The action is something like the effect called the "mirage" as regards light, which will be found described in any book on optics. The heated layers of air near the earth bend the light rays coming from distant objects so as to make an apparently inverted image of them appear to the observer, which suggests the idea of reflection at the surface of water. This ionic refraction, which is a sort of inverted mirage action, bends the electric waves right round the earth and so enables us to conduct wireless telegraphy with the antipodes. The advantage of very long electric waves is that the range is not much affected by moderate changes in the height of the ionised layer at various times during the year.

Hence long-wave radio stations such as the Rugby station of the British General Post Office are useful and important for all-the-year-round long-distance wireless communications.

How Short and Intermediate Waves are Affected

On the other hand, for the short and intermediate waves, 50 to 200 or 400 metres long, the effect at a distance is due to a direct wave travelling along the earth's surface and to a wave or waves reflected or refracted by the lower surface or margin of the ionised layer of air.

Just as at sunset, long after the sun has sunk below the horizon and ceased to give us direct rays of light, other rays are sent up to the sky and reflected down again by the clouds and so give us twilight and sunset illumination.

Now the height of the lower surface of the ionised layer is continually varying. It is different by day and by night, and in summer and winter, and at times almost from instant to instant.

Hence with this range of wavelength the effect at the receiver is a complex one, due partly to a direct ray and partly to a reflected ray, and the proportion contributed from each ray varies with the distance, the frequency or wavelength and with the state at the time of the ionised layer.

What the "Skip Distance" is

The direct ray is attenuated or weakened by absorption in passing over the earth's surface or the sea, and at a certain distance the direct ray may be so weak as to produce no receiving effect at all. On the other hand, the reflected ray may not have come down fully to the earth, and there is therefore a range of bad reception called the *skip distance.* As this skip distance continually varies it is the cause of a great deal of the irregularity in broadcast reception. Thus, for instance, the writer, living at Sidmouth in Devon, can receive Rome and other short-wave stations well during the winter, but not at all during the summer and only variably during spring and autumn evenings. This is largely due to the variations of skip distance.

Table of Average Skip Distances

In the *Marconi Review* for January–February, 1932, a useful table was given showing the average skip distance for various wavelengths in day and night and summer and winter. It is as follows :—

Wave-length in metres.	Skip distance by day in miles.	Skip distance by night in miles. Summer.	Winter.
15	900	5,000	infinity
20	600	1,400	infinity
30	300	700	4,000
40	250	350	1,500
60	200 about	250	350
80	0	250 about	200
100	0	250	200

The figures in the last three rows are very liable to variation.

The Beam System

In 1924 the Marchése Marconi published accounts of his researches with electric waves of only 30 metres, or 100 feet in wavelength, and he showed that such waves could be used for reliable telegraphic communication by day as well as night over great distances, even to the antipodes. These waves are projected in a beam from a flat system of vertical wires called a beam aerial. The vertical wires are cut up into sections separated by non-radiative inductance coils and such an aerial can project a powerful beam of radiation of about, say, 15 or 16 metres wavelength by suitable construction. For long waves greater than 100 metres the daylight range is much shorter than the night range, but for 16-metre waves it is not so, and by a 32-metre wave radio communication with Australia is possible with a power of not more than 10 to 12 kilowatts.

Cause of Fading

The sudden fading away in the loudness of broadcast music which frequently takes place on certain wavelengths between about 200 and 500 metres is largely due to variations in skip distance. It may also be partly due to interference between the direct and reflected ray which takes place when their phases differ by an odd multiple of half a wavelength owing to difference in distance travelled over.

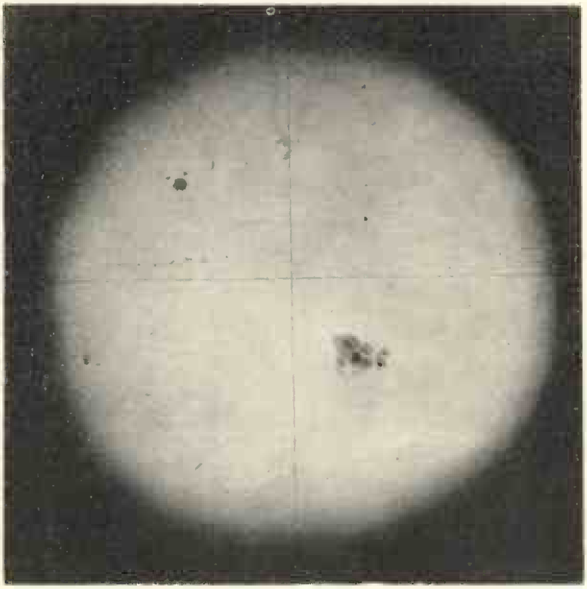


Photo: Royal Observatory, Greenwich.

Fig. 7.—A GENERAL VIEW OF THE SUN, SHOWING SUNSPOTS.

Sunspot periods exercise a decided influence on long-distance wireless telegraphy. At about the period of maximum sunspots the ionised layer descends to a lower average level of the atmosphere. The result is to favour the use of short waves and small power for transmission.

This may take place for distances at which the reflected ray comes down to the ground at some point within the range of the direct ray.

It will next be necessary to point out the relative advantages or disadvantages of waves of particular wavelength — long, short or ultra short.

Generally speaking, we can say that the direct or ground wave, as it is called, suffers far more attenuation than the reflected ray. The direct ray is far more weakened by travelling over land areas than over sea areas, and some land areas seem to have a specially absorbent character.

Long High Energy Waves

Hence in selecting a wavelength for long-distance working by ground waves we have to employ one with large energy at the start so as to have an allowance for dissipation of energy. Accordingly there is an undoubted advantage in the use of long high energy waves. But these require large and expensive generating plant, either high-frequency alternator, or, better, large thermionic valve plants of metal and dismountable valves.

Shorter Waves and their Advantages

On the other hand, the shorter waves which travel to the receiver through the air and by reflection at the under surface of the ionic layer suffer very little attenuation and need not possess so much energy at the start. They require less powerful and less expensive transmitting plant.

Speed of Signalling

Then there is another advantage in speed of signalling. In order that the receiving apparatus may record a signal it is necessary that a certain number of oscillations should be set up in it to accumulate the necessary amplitude. This requires a longer time with longer waves. If we attempt to signal too quickly, either we get no record at all at the receiving end or else the dots and dashes of the Morse code would run together into an unbroken line. Also, with shorter waves and higher frequency signalling can be quicker. The advantage is, however, not all on the short-wave side. The fading and variation of skip distance and a certain class of disturbance are greater for the shorter waves than for the very long.

There are, however, certain decided advantages in the use of very short waves of a few centimetres in wavelength.

Marconi's Ultra Short Wave Apparatus

The Marchése Marconi has been developing their use for short-distance wireless telephony of late years. The type of transmitter he employs consists of a rod Hertzian oscillator which is placed horizontally and is fixed at the focus of a parabolic former of wood or non-conducting material. To this are fixed a number of rod reflectors which are parallel to the rod oscillator, and these serve to collect all the radiated waves from the oscillator and reflect them in a parallel beam of very short wave radiation. Oscillations are generated in this rod oscillator by a special form of thermionic valve generator. The wavelength employed is 50 centimetres. Hence the rod oscillator is rather less than 25 centimetres long, or less than 1 foot.

Nevertheless, with this ultra-short-wave apparatus Marconi has communicated by wireless telephony a distance of twenty-five miles.

Advantages and Disadvantages

The advantages claimed for this ultra-short-wave system is that of freedom from atmospheric disturbances and very small power expenditure. On the other hand, there must be no solid or opaque objects in the line of sight or part of a great circle line connecting the sending and receiving stations.

The system is said to be particularly adapted for telephonic speech between islands and the mainland not more than twenty-five miles away, and where the small traffic would not justify an expensive installation or telephone cable.

Influence of Sunspots

There is another important question with regard to the selection of wavelengths and power for certain definite communications, and that is the influence of sunspots upon wireless transmission.

It has been known for many years that the eruptions and cyclones on the sun's photosphere vary in number from day to day and year to year. The maximum number occur, roughly speaking, every eleven years, but that period is not constant and may fluctuate between nine and thirteen years. Certain other well-known electric and magnetic phenomena, such as polar auroræ and magnetic storms, fluctuate periodically with the number of sunspots. Since the sun is the cause of the ionisation of the upper atmosphere, it has an indirect effect on wireless telegraphy. It appears that at and about the period of maximum sunspots the ionised layer descends to a lower average level of the atmosphere. The result is to

(*Contd. on p. 406*).

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION VIII—CONDENSERS

THE electrical condenser is one of the most important pieces of apparatus in radio engineering. Glance at the theoretical diagram of any circuit and you will find that condensers are used freely everywhere, be it the tuning circuit, the detector circuit, the amplifying circuits, the output circuit or the mains supply circuit. There are many radio experimenters and constructors who are at a loss to understand fully the action of this important component, and the majority of them are still struggling with the problem of the condenser serving as a stop to direct currents and yet allowing an alternating current to " go through."

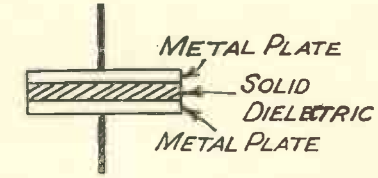


Fig. 1.—A TWO-PLATE CONDENSER WITH SOLID DIELECTRIC.

This may be mica, ebonite, glass, paraffined paper, etc.

A Condenser Stops any Current

As a matter of fact, a condenser will stop any current, be it direct or alternating, but in the case of the latter there is, one may say, a secondary action, that of discharge at timed intervals which gives the impression that somehow the condenser does not behave in the same way with alternating currents as it does with direct currents.

Let us consider carefully this question, so that all the old doubts are cleared away once for ever.

What a Condenser is

Generally speaking, an electric condenser represents an even set of metal plates separated from each other by some insulating substance. Dry air is a good insulator, and for this reason condensers are often made of spaced plates with air as insulator.

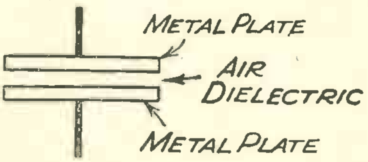


Fig. 2.—A TWO-PLATE CONDENSER WITH AIR USED AS A DIELECTRIC.

It is usual to talk of the insulating substance separating the plates of a condenser as *dielectric*, and in future we shall use this name in preference to any other.

In Fig. 1 we see a two-plate condenser with solid dielectric. This may be mica, ebonite, glass, paraffined paper, etc. In Fig. 2 is shown a two-plate condenser with air used as a dielectric. In Fig. 3 the condenser consists of four plates joined in pairs and separated by a solid dielectric. In Fig. 4 we have a similar condenser, but with ir dielectric.

Two Main Types—Fixed and Variable

Electrical condensers can be divid d into two main types—*fixed condensers* and *variable condensers*. In the case of a fixed condenser the plates and the dielectric are immovably clamped together and form a rigid fixed structure. In the case of a variable condenser one set of plates, or *vanes*, as these plates are usually called, is capable of moving in respect of the other set of vanes.

Simplest Form of Condenser

Now let us consider the simplest form of a fixed condenser consisting of two plates separated by air.

In Fig. 5 we have such a condenser wired to two contact studs 1 and 2, and we also have a battery with flexible leads *a* and *b*. If we connect the lead *a* to stud 1 and the lead *b* to stud 2 we shall have the plate 1 of the condenser at the same potential as the negative termina of the battery and the plate 2 at the same potential as the positive terminal of the battery.

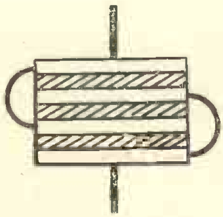


Fig. 3.—A Condenser of Four Plates Joined in Pairs and Separated by a Solid Dielectric.

A Charged Condenser

In other words, by connecting the battery *across* the plates of the condenser, as shown in Fig. 6, we have made the plate 1 rich in electrons and the plate 2 poor in electrons. Each plate of the condenser now has an electric charge, and we say for this reason that the condenser, as a whole, is *charged*.

You will notice in Fig. 6 that there is no electrical *continuous* circuit, although the condenser appears to complete this circuit. The E.M.F. of the battery cannot drive electrons *round the circuit*, from its negative terminal to its positive terminal, as the two plates of the condenser are separated by an insulating substance (air). In this manner, when the battery is at first connected, as shown in Fig. 6, all that will happen is that there will be a *momentary* surge of electrons from the negative terminal of the battery to the plate 1 of the condenser, and also a simultaneous surge of electrons *from* the plate 2 of the condenser to the positive terminal of the battery.

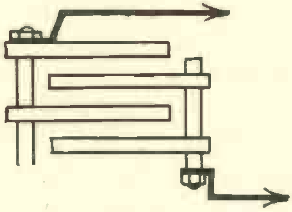


Fig. 4.—A Condenser of Four Plates, but with Air Dielectric.

The reason for this is that on the negative terminal of the battery there is a comparatively large excess of electrons which repel each other, and, as the repulsion from the *balanced* electrons of the plate is much less than the repulsion from the negative terminal of the battery, the surplus electrons will invade the surface atoms of the plate 1. It should be borne in mind that before the battery was connected to the condenser, the plates of the latter were electrically neutral, *i.e.*, every electron was balanced by its proton.

At the positive terminal of the battery, which is poor in electrons, there is a comparatively large preponderance of protons, and these unbalanced protons will attract towards themselves all the "planetary" electrons they can attract from the plate 2.

The Charging Current

This simultaneous surge of electrons from the negative terminal of the battery to the plate 1 and from the plate 2 to the positive terminal (a surge *in the same direction*, you will notice, all round the circuit, with the exception of the space between the plates of the condenser) is called the *charging current*.

Strength of the Charging Current

The strength of this *instantaneous charging current* (a current of very short duration) will depend upon two things—the E.M.F. of the battery and the capacity of the condenser. Since an atom can accept only a limited number of surplus "planetary" electrons, a plate of a condenser as a whole can accept only a limited number of surplus electrons. Similarly, it can lose a limited number of electrons. Thus it is clear that we cannot charge a condenser indefinitely, but only up to its limits.

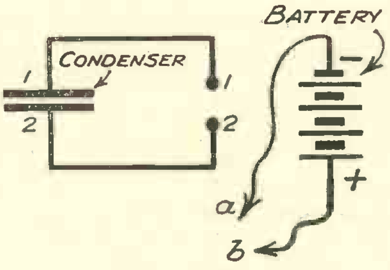


Fig. 5.—Showing a Condenser Wired to Two Contact Studs, 1 and 2, and a Battery with Flexible Leads *a* and *b*.

The Capacity of a Condenser

From the above it is clear that the larger the area of the plates the greater will be the capacity of the condenser, as the more surface atoms a plate has the more electrons it can accept as a whole.

Thus *the capacity of a condenser grows with the growth of the area of the condenser plates.*

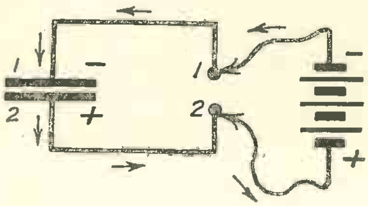


Fig. 6.—Effect of Connecting a Battery Across the Plates of a Condenser.

Plate 1 has been made rich in electrons and plate 2 poor in electrons.

Points which Govern the Capacity of a Condenser

Let us consider now another point of importance. With a given area of condenser plates it is possible to increase the capacity of the plates by bringing them closer together. In considering Fig. 7, which shows a charged condenser with the battery removed, we see at a glance that there must be an attractive force between the unbalanced protons on the plate 2 and the surplus electrons on the plate 1. If these two plates are brought closer and closer together, the surplus electrons on the plate 1 will be attracted towards the protons on the plate 2, accumulating on the side of the plate nearest to them. In this manner a number of surplus electrons on the plate 1 will leave some of the surface atoms on one side, and will thus clear the way for the arrival of some more surplus electrons.

When the Plates are Far Apart

Normally, when the two plates of the condenser are a large distance apart, the capacity of the condenser will be largely governed by the number of the surface atoms which can only accept a limited number of surplus electrons. But when an external attractive force comes into existence, such as described above, due to the attraction of protons, the electrons will bunch up as close as possible to the attracting force, making room for some more surplus electrons in the evacuated atoms.

Similarly, in the plate 2, when a number of unbalanced protons are occupied in attracting electrons from the other plate, they will relax the force of attraction on their own electrons, so that more of them can be withdrawn to the positive terminal of the battery when the latter is connected to the plate 2 of the condenser.

It is clear, therefore, that *the capacity of a condenser will increase with the decrease of the distance between the plates of the condenser.*

The Dielectric

But this does not finish the story. The attraction of the surplus electrons on one plate of a condenser by the unbalanced protons on the other plate has to take place through the dielectric separating the two plates. The dielectric, being a complex substance, has its planetary electrons strongly bound to the nuclei in the atoms, so that a much greater force is required to remove a planetary electron from an atom within a molecule of an insulating substance than from an atom of a metallic conductor. This is the reason why an insulating substance has a much greater resistance than a conductor.

Attraction of Surplus Electrons

In considering the attraction of surplus electrons on one plate by the unbalanced protons on the other plate we can easily see that the unbalanced protons will not act directly upon the surplus electrons on the plate 1, but in the first instance will attract towards themselves some of the electrons in the atoms of the dielectric, and will unbalance some of the protons in these dielectric atoms. The latter protons will act in a similar manner upon the next layer of atoms in the dielectric, and so the process will go on till the electrons on plate 1 are acted upon by unbalanced protons

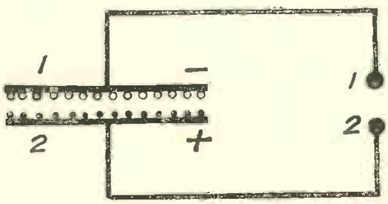


Fig. 7.—A Charged Condenser with the Battery Removed.

in the surface atoms of the dielectric next to them.

Why the Dielectric Affects the Capacity

It is thus seen that the dielectric takes an active part in the attraction of surplus electrons on one condenser plate by the unbalanced protons on the other plate. And as this attraction affects the capacity of the condenser as a whole, it is clear that the dielectric affects this capacity in some way or other.

Dielectrics differ in composition. Some have their atoms much more stable than others, *i.e.*, in some the "planetary" electrons are bound to their nuclei much more than in others.

Effects of Dielectrics on Electrostatic Induction

Since attraction at a distance between protons and electrons is called *electrostatic induction*, we can say that some dielectrics facilitate this induction more than others. In other words, since a dielectric may be said to determine the number of electrons and protons attracting each other, and thus to determine the amount of additional capacity the plates of a condenser may possess, we can say that every dielectric has a certain *specific inductive capacity*.

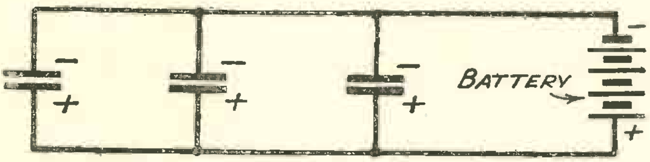


Fig. 8.—CONDENSERS JOINED IN PARALLEL TO OBTAIN LARGER CAPACITIES.

The specific inductive capacity of air is taken as unity, and the specific inductive capacities of other dielectrics are expressed in figures which indicate how many times the specific inductive capacity of the dielectric is greater than that of air.

Thus the specific inductive capacity of ebonite is 2 to 3·5 times that of air; glass, 4 to 10; mica, 5; india-rubber, 2·12 to 2·3, and so on.

To sum up: *the capacity of a condenser depends on the total area of the plates, the distance between them and the nature of the dielectric between the plates.*

Why a Dielectric may Break Down

We can see from the above that when a condenser is charged, whatever the distance between the plates, there is always some attraction between the surplus electrons on one plate and the unbalanced protons on the other plate. Since this attraction is taking place *viâ* the atoms of the dielectric and is causing a shift of electrons within its atoms, the atoms themselves will also be suffering a certain amount of displacement, and for this reason the dielectric will be subjected to a certain amount of *strain*. It is easily visualised that should this strain become excessive the atoms of the dielectric will break down and open up a clear path for the flow of electrons from one plate to another. This sort of thing often happens in practice, and the dielectric becomes actually punctured in the case of solid dielectrics and becomes ionised in the case of air. In each case a conducting path is provided for the electrons, and the condenser ceases to act as a condenser.

Dielectric Strength

In order to distinguish between the resistance to such rupture of different dielectrics, or, in other words, in order to distinguish between the *dielectric strength* of materials, the latter are made up in plates 1 millimetre thick and subjected to the influence of different voltages. The voltage which ruptures the plate of a given material is called the voltage equivalent to the dielectric strength of this material, or simply the dielectric strength of the material.

Thus it requires 40,000 volts to break through a millimetre thick sheet of india-rubber, 50,000 volts for ebonite, and 60,000 volts for mica.

A Thick Dielectric is Weaker than a Thin One

Although it may appear absurd at the first glance, a thin sheet of dielectric is stronger from the above point of view than a thicker sheet. This means that a sheet of dielectric ½ inch thick is not twice as strong dielectrically as a sheet of the same material ¼ inch thick.

The reason for this apparent anomaly is that in the case of a thick slab of dielectric, owing to the multiplicity of atoms taking place in the displacement from their original position under the influence of the attractive force of protons on the positive plate, there is always a danger of electrons bunching up at one spot, a bunching up which in producing a large surplus of electrons at one point facilitates the breaking through of these electrons across the dielectric.

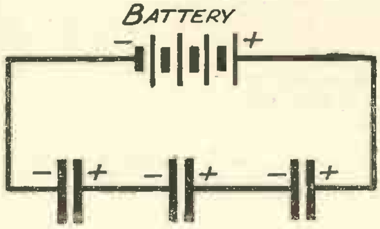


Fig. 9.—CONDENSERS JOINED IN SERIES TO OBTAIN SMALLER CAPACITIES.

Condensers in Parallel

When larger and larger capacities are required, condensers are joined *in parallel*, as shown in Fig. 8. Here the total capacity of the arrangement is equal to the sum of the capacities of individual condensers. From Fig. 8 it is easily seen that such a method of connection is equivalent to increasing the total plate area.

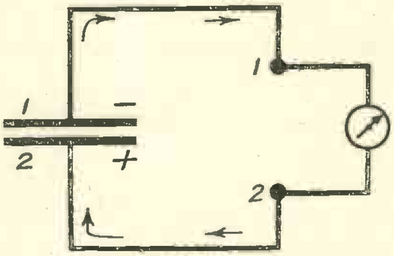


Fig. 10.—SHOWING HOW A MOMENTARY CURRENT WILL FLOW ON DISCHARGING A CONDENSER.

Condensers in Series

Very often one has a number of condensers of given capacities, and requires a capacity smaller than any one of them. In this case the condensers are connected *in series*, as shown in Fig. 9. It is interesting to note the distribution of charges on the condenser plates in the case of a series connection. The net result of such connection is that while the plate area of the combination remains the same as in the case of a single condenser, the number of dielectric slabs is increased, hence the total capacity is diminished.

If three condensers of equal capacity are joined in series, the resultant capacity of the combination is a third of the capacity of a single condenser. This is the reason why, if we want to reduce the capacity of an aerial, we connect a fixed condenser in series with it.

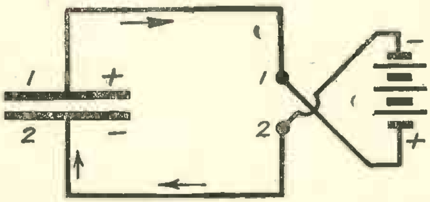


Fig. 11.—SHOWING EFFECT OF REVERSING CONDENSER AND BATTERY CONNECTIONS SHOWN IN FIG. 6.

Plate 2 of the condenser will now become negative, and Plate 1 positive.

Behaviour of Condensers on Charge

Having made our acquaintance with the factors determining the capacity of a condenser, and having left the mathematical considerations of this problem to our mathematician, let us proceed with the studies of behaviour of condensers on charge.

Discharge Current

If we turn again to Fig. 7 we shall see at a glance that the condenser after charge, having one plate negative (surplus of electrons) and the other plate positive (deficit of electrons), resembles a small cell. This fact is confirmed if we place an indicating instrument, such as a galvanometer, across the plates of the charged condenser. A *momentary current* will flow from one plate to the other, as shown in Fig. 10. This instantaneous current is called the *discharge current* of the condenser.

When discharging, the condenser sends electrons from plate 1, *viâ* the indicating instrument, to plate 2, which is poor in electrons. On comparing Figs. 6 and 10, you will see that the charging and the discharge current are flowing in the opposite directions. After the discharge the condenser will become neutral.

Taking once more the condenser and the battery shown in Fig. 5, and connecting the lead *b* to stud 1 and the lead *a* to stud 2, we shall have a state of affairs as shown in Fig. 11. Plate 2 of the condenser will now become negative and plate 1 positive, and the charging current will flow as shown.

The discharge current will now flow from plate 2 to plate 1, as shown in Fig. 12.

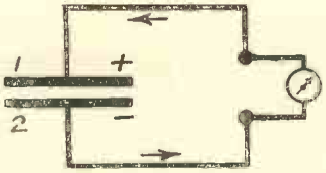


Fig. 12.—Showing how the Discharge Current will Flow from Plate 2 to Plate 1.

Current does not Flow Right Round the Circuit

I trust that it is quite clear by now that in the case of a condenser there is no question of current flowing right round the circuit, but that the charging E.M.F. merely takes away the electrons from one plate (leaving there a number of protons exposed), and transfers them on to the other plate. Please note carefully that *what is missing on one plate is in surplus on the other plate.* The discharge current merely flows from the plate which happens to be rich in electrons to the plate which is poor in electrons, when the two plates are joined together.

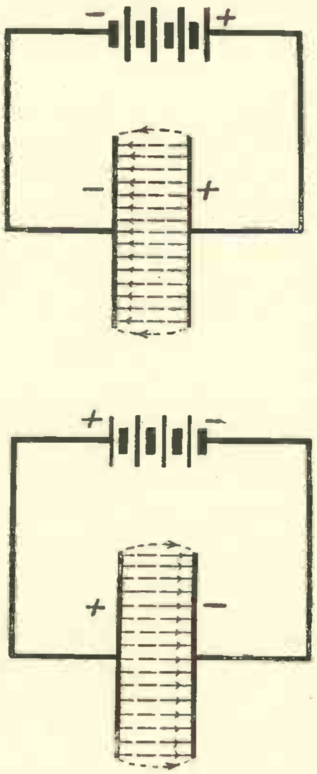


Fig. 13.—This shows the Electric Field between the Two Plates of the Condenser.

How the Charging and Discharging of a Condenser is Timed

When we charge a condenser and make one plate or one set of plates poor in electrons and the other plate or set of plates rich in electrons and remove the charging E.M.F., we have a means of storing electrical energy. A charged condenser, if left alone, will keep its charge for some time. In this manner we can *time* the charging and discharging of a condenser, and thus have a means of controlling the flow of electrons at will. Such a timing of discharge current can be carried out with the help of a variable E.M.F., such as an alternating E.M.F.

Units Used for Measuring Condenser Capacities

The action of an alternating E.M.F. upon a condenser will be considered in the next section, but in the meantime let us make ourselves familiar with the units used in measuring condenser capacity.

The Coulomb

The quantity of electricity contained in an electron or a proton (these quantities are identical) is too small for practical purposes. For this reason, in order to measure the quantity of electricity on a practical scale, we use a unit called *coulomb.*

One coulomb represents the quantity of electricity contained in $6{\cdot}29 \times 10^{18}$ (6,290,000,000,000,000,000) electrons.

From this is derived the unit of electric current of 1 ampere, which is the flow of 1 coulomb per second past a given point of the circuit.

Now *a condenser is said to possess a capacity of 1 farad if it can accommodate 1 coulomb of electricity when an E.M.F. of 1 volt is applied to it.*

A Microfarad and Micro-microfarad

But such a unit is far too large for wireless work.

For this reason we use smaller units, fractions of a farad, of which the most usual is the *microfarad* (one-millionth of a farad) and the *micro-microfarad* (a millionth of a millionth of a farad).

Capacity is also sometimes expressed in centimetres. In these units 1 farad is equal to 9×10^{11} centimetres.

In the Navy they used to measure capacity in jars (derived from the Leyden jar). One jar is equivalent to 1,000 centimetres, so that 1 farad is equal to 9×10^{8} jars.

Electric Field between Plates of a Condenser

In conclusion of this article, it is necessary to note another phenomenon in connection with charged condensers.

We know that there is an electric field in existence around an electron and a proton, and when the two are near together this electric field, consisting of lines of force, starting on the proton and terminating on the electron, spreads from the proton to the electron. It is clear, therefore, that when one plate of a condenser has a surplus of electrons and the other plate has a deficit of electrons, which means a predominance of protons, there will be an electric field between the two plates of the condenser, as shown in Fig. 13. This electric field will establish itself in the dielectric, acting upon the planetary electrons of its atoms and displacing them slightly, as already explained.

The greater the charge on the condenser the greater the field between the plates (the more lines of force). It is necessary to note that the direction of the electric field changes with the change of polarity on the plates. If an alternating E.M.F. is applied across the plates of the condenser, we shall have an alternating electric field between the plates of the condenser. This we shall consider in the next section.

THE NATURE AND PROPERTIES OF WIRELESS WAVES

(*Continued from page* 399)

favour the use of short waves and small power for transmission.

Sunspot Periods

We are now approaching a minimum sunspot period which will happen about 1933–1934. Accordingly the maximum came about 1929. Hence the years from 1924 to 1928 saw a gradually increasing number of sunspots and a steady improvement in conditions for good short-wave propagation over long distances. But it is now recognised that the conditions for such good use of waves, say of 13 to 15 metres in length, across the North Atlantic are passing away, and it may mean a re-equipment and change of wavelength for the beam stations now using such waves and the employment of a longer wavelength with great power expenditure and more liability to disturbance. In short, it seems as if the eleven-year period of sunspot frequency will exercise a very decided influence on long-distance wireless telegraphy.

Experiments that are being Carried Out

The matter requires further investigation. Only quite lately (in July, 1932) an expedition was despatched by the British Radio Research Board, under the leadership of Professor E. V. Appleton, to Tromsö in Norway to conduct experiments in conjunction with other expeditions sent by America, France, and Holland to other places in high latitudes to endeavour to discover how far solar activity affects the ionic state of the earth's atmosphere and hence the conditions for wireless telegraphy with the shorter wavelengths.

The whole of the important questions concerning the selection of wavelengths for short-wave beam transmission are therefore undergoing careful inquiry.

RESISTANCES

USE AND SELECTION

By EDWARD W. HOBBS, A.I.N.A.

A RESISTANCE in electrical and wireless work is a device specially introduced into a circuit to oppose the flow of an electrical current. The nature, value and form of the resistance are determined by its purpose.

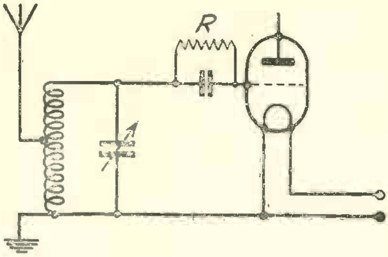


Fig. 1.—GRID LEAK IN SIMPLE VALVE SET.

The resistance R is shunted across the grid condenser. It may have a value of about 2 megohms.

Types of Resistances

The simplest form of resistance consists of a coil of wire made from a metal or alloy that possesses a high degree of resistivity; others consist of carbon or metallic compositions of various sorts enclosed in a carton of some kind with metal contacts at each end.

The resistivity of a metal is compared to that of silver, which is taken as 1; soft iron is seven and a half times as high; German silver eighteen times; some alloys of hard steel are twenty-one times higher than that of silver.

Nickel-chrome steel is extensively used for wire-wound resistances on account of its strength and electrical properties.

Unit of Resistance

The unit of resistance is the ohm, which is that resistance which allows one ampere to flow when unit voltage is applied across it.

It is important to grasp these relationships so that the correct value of resistance can be used in a circuit and, furthermore, that a suitable kind may be selected which will safely carry the required amount of current without overheating or burning out.

In practice the safe current-carrying capacities are stated by the makers of the resistances; all that the wireless constructor has to do is to select the correct type and value of resistance.

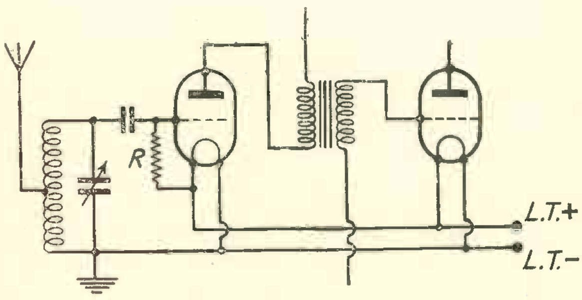


Fig. 2.—GRID LEAK IN TWO VALVE SET.

When the first valve is the detector and is followed by L.F. stages, the grid leak R is connected between grid and low tension plus.

APPLICATIONS OF RESISTANCES

The Grid Leak

One of the simplest but most important applications of a resistance in a wireless set is that used in the grid circuit of a detector valve and generally known as a grid leak.

These are generally of the composition type in small sets, and may have values of from ¼ to 5 megohms.

In the case of a single valve receiver the grid leak is shunted across the grid condenser, as in Fig. 1, but when the first valve is the detector and is followed by L.F. stages, the grid leak should be connected, as shown in Fig. 2, between the grid and the low tension + lead of a battery-driven set, and may have a value of about ½ megohm, used in conjunction with a grid condenser with a capacity of ·0002 mfd.

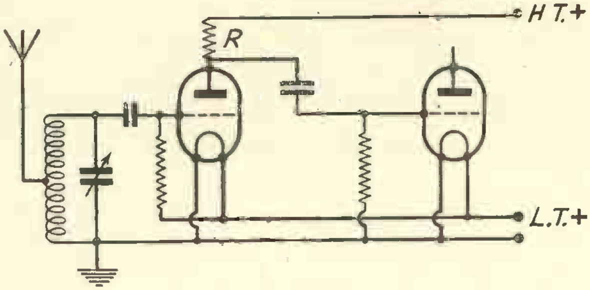


Fig. 3.—Anode Resistance.

Skeleton circuit of a resistance capacity coupling. The method of determining the values of resistance R is given in the text.

More complicated circuits may have the grid resistance connected either to negative or positive low tension, or to a potential divider or a potentiometer, according to the desired biassing of the detector grid.

Anode Resistances

These are used in the anode circuit of a valve, generally wire wound, non-inductive and enclosed in a carton or casing of some kind with terminal or tag connections at each end.

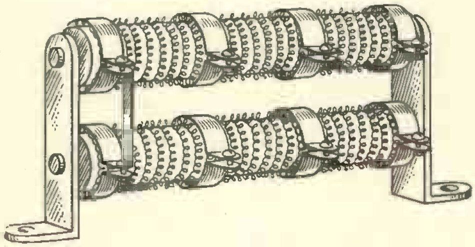


Fig. 4.—Tapped Anode Resistance.

A useful resistance, with centre tap and adjustable tapping clips.

An example of the use of such resistances is the simple resistance-capacity coupling between a detector valve and a L.F. valve, of which a skeleton circuit is shown in Fig. 3, with the coupling resistance R, but without the usual choke and decoupling arrangements.

As a general guide, the value of the coupling resistance should be about three to four times that of the impedance of the valve, thus with a valve having an impedance of 18,500 ohms, the anode resistance may be of the order of 70,000 to 80,000 ohms.

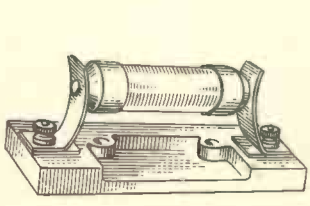


Fig. 5.—Cartridge Type Resistance and Holder.

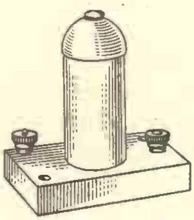


Fig. 6.—Grid Bias Resistance.

Tapped Anode Resistances

When relatively heavy currents have to be handled, as in the case of power amplifiers, it is essential to use a special type of heavy duty resistance, such as the Bulgin, Fig. 4, consisting of a wire-wound resistance on porcelain formers supported on uprights. It should be placed in the set so that there is ample space around the resistance to allow for heat radiation. By winding the resistance in two halves it can be centre tapped and the two parts used respectively as anode and decoupling resistances.

Values range from 2,000 ohms 100 milliamps, to 20,000 ohms 30 milliamps. Adjustable clips enable the resistances to be tapped at any convenient points.

Anode Feed Resistances

The "Ferranti" cartridge type resistance, Fig. 5, has a dissipation of 2½ watts, is wound in sections and enclosed in a cartridge with metal contact ends which spring into a special holder, the standard range is 300 to 100,000 ohms, see table on page 412. The power type by the same firm dissipates 10 watts and ranges from 500 to 8,000 ohms.

Other types are made with the resistance in a neat moulded casing, in appearance like a fixed condenser, while others combining a resistance or resistances and a fixed condenser are on the

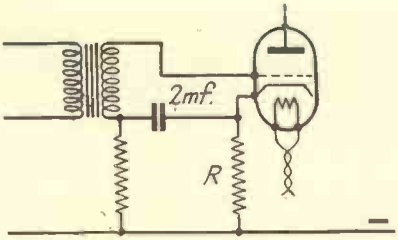


Fig. 7.—GRID BIAS RESISTANCE IN A CIRCUIT.

Showing how the resistance R is incorporated in an all mains set.

market and result in great economy of space and simplification of layout.

Grid Bias Resistances

An example of this type is the "Tunewell"—shown in Fig. 6. They are non-inductively wound with impregnated D.S.C. Eureka resistance wire on sectional bobbins and enclosed in a moulded Bakelite casing with terminals on the base. Values up to 1,500 ohms.

The application of such a resistance in a skeleton circuit for an all-mains set is shown in Fig. 7.

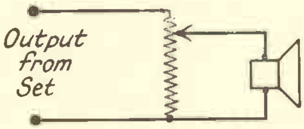


Fig. 9.—POTENTIOMETER IN LOUD SPEAKER CIRCUIT.

Here the resistance is shunted across the output leads and the movable contact connected to one of the loud speaker leads.

Variable Resistances

There are numerous types, which can roughly be grouped into three sections: first, the plain straight-slider type, now nearly obsolete; secondly, the circular type; and, lastly, the tapped variety with selector switch.

Claims for the tapped variety are that the studs and tappings eliminate wear on the resistance element which can then be wound with covered wire. In one make, 14 contact studs are used with equal resistance values between each, giving a smooth control suitable for variable dropping resistances, while a similar variety, but wound logarithmically, is suited to volume controls. Average dissipation is about 3 watts, resistance 50,000 ohms.

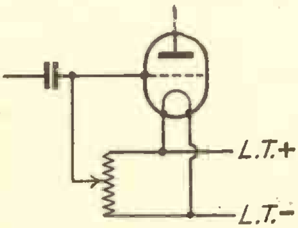


Fig. 10.—POTENTIOMETER CONTROL OF GRID BIAS.

A potentiometer across the low tension filament leads enables positive, negative, or zero bias of the grid.

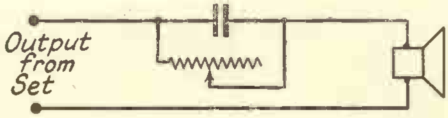


Fig. 8.—VARIABLE RESISTANCE AS TONE CONTROLLER.

The amount of bass response can be regulated with a variable resistance shunted across a condenser in one lead to a loud speaker.

One application of a variable resistance is shown in Fig. 8, where it is shunted across a condenser in series with a loud speaker.

The purpose here is to control the tone of the speaker; when the resistance is in circuit the bass is diminished according to the value of resistance and electrical characteristics of the circuit and the speaker.

An average value for the resistance is about 10,000 ohms with a $\frac{1}{4}$ mfd. to 1 mfd. condenser.

The treble can be controlled by putting the condenser in series with the resistance and shunting both components across the loud speaker.

Variable Potentiometer

The "Lewcos" is an excellent example of a high resistance wire-wound variable resistance or potentiometer with a patented double helical winding enabling an extraordinary length of wire to be wound in a very small space. Contact is made by means of a rolling disc which can be rotated by an external

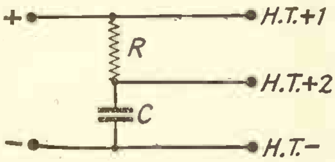


Fig. 11.—ANODE FEED SYSTEM.

A voltage drop is obtained between H.T. + 1 and H.T. + 2 by the resistance R.

knob. This ingenious device gives the finest possible adjustment of voltage without any rubbing friction on the windings.

This type of resistance is available up to 500,000 ohms resistance, but a smaller model with the same advantages is available from 1,000 ohms 45 milliamps, to 50,000 ohms 7 milliamps, either with constant increment windings or with increasing increment or graded windings.

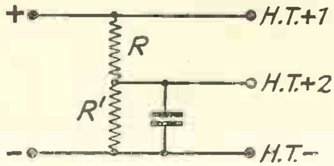


Fig. 12.—Screen Grid Feed Resistances.

Two fixed resistances used to control the voltage to the screen of a S.G. valve.

The advantage of the logarithmic or graded potentiometer over a standard or constant increment winding gives a more uniform increase or decrease of response irrespective of the potentiometer arm position. The resistance of a potentiometer used as a tone control should be about the same as the resistance in ohms of the loud speaker.

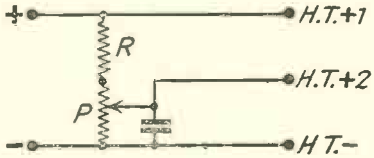


Fig. 13.—Resistances and Potentiometer Control.

Substituting a potentiometer P for the resistance R1 of Fig. 12 enables the screen voltage to be varied for maximum results.

Wire-wound Spaghetti Resistances

Under this general heading will be found a variety of makes, differing somewhat in detail. The "Tunewell" has a braided silk covering over the resistance wire, and open tag ends.

The "Bulgin" wire element is electrically spot-welded to a coiled copper connection to the tag ends.

The "Lewcos" resistances are wound on a special core, have double grip terminal tags, and are very flexible. They can be knotted when necessary to reduce their mechanical length, without loss of electrical efficiency.

The standard range of Lewcos Spaghetti Resistances is summarised in the following table.

Intermediate values of resistances in the "Lewcos" range are not given in the table.

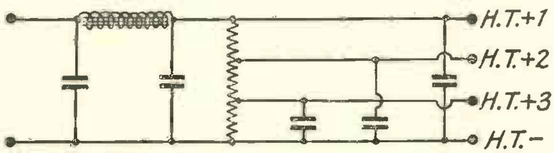


Fig. 14.—Potential Divider.

A fixed resistance with tappings at equal divisions here provides three different voltage outputs.

Standard Range of Lewcos Spaghetti Resistances

Ohms.	Current M/Amps.
300 to 1,000	50
2,000–3,000	20
4,000–5,000	15
7,500–15,000	10
20,000–40,000	7½
50,000–100,000	6

Bulgin Biassing Spaghettis for Heavy Duty Purposes

These are intended for biassing mains valves or other heavy duty purposes, the current carrying capacity is higher than the usual spaghetti types. The normal range is as follows :—

Ohms.	Currents M/Amps.
200	70
240–300	65
330–500	60
600–1,000	50
1,250–2,000	40

Applications of these resistances are too numerous to particularise, they can be used in almost any home constructor set, and are simply clamped in place by the terminal nuts on the components they connect.

Wire-wound Resistances

These are wound on an insulating core and have terminals and clip connections at each end.

The Dubilier Spirohm wire-wound resistances are designed for loads up to 10 watts. A larger size capable of dissipating twenty watts can be obtained. The following table gives resistance values and corresponding maximum permissible current values in milliamperes.

Intermediate values can be obtained by connecting to an additional tapping clip.

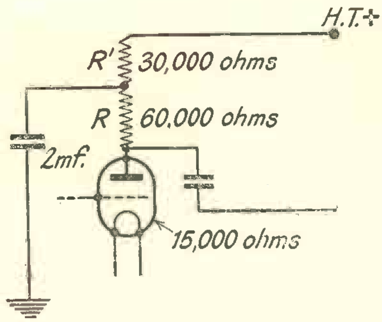


Fig. 15.—Decoupling Resistance.

A resistance is here shown at R[1] which opposes the H.F. currents and by-passes them through the 2 mfd. condenser to earth.

"Spirohm" Resistance Ranges

Resistance in ohms and maximum permissible current in milliamperes.

Resistance ohms.	Current M/Amps.
200	200
500	140
1,000	100
2,500	60
5,000	45
7,500	35
10,000	30
20,000	20
30,000	15
50,000	10

Direct Current Mains Resistances

Employed to reduce the voltage from the mains, they must in all cases be well spaced from any other fittings or from the sides of the cabinet, as they have to dissipate some 50 watts or so in the form of heat depending on the current required.

Such resistances are usually wound with nickel-chrome wire on porcelain or heat-resisting tubes, having tapping bands or clamp rings and terminals.

Voltage Dropping

Provision of various output voltages from an eliminator can be obtained by various methods, including the anode feed system shown in Fig. 11, which by use of a suitable resistance R and a condenser C reduces the voltage of the H.T. tap and acts as a decoupler, the condenser by-passing unwanted frequencies to earth.

The value of resistance R can be calculated if the load or maximum voltage is known, and the required anode voltage and current. Deduct the lower voltage from the maximum, divide this by the current flowing through the resistance in milliamperes, and multiply by 1,000 to obtain the value in ohms for the resistance. For example, with a maximum voltage of 150 and detector anode voltage of 90 the voltage to be dropped is 60. Assume the current is 3 m.a., then

$$\frac{60}{3} \times 1{,}000 = 20{,}000 \text{ ohms.}$$

Determining Resistance Values

When two or more resistances are used in series to provide various voltage outputs—as, for instance, the supply to a screen grid valve or anode bend detector—the current flow is in such cases quite small, and to avoid undesirable fluctuations the value of the potentiometer or potential divider must be such that about four times the current taken by the valve will flow through it. The skeleton circuit is shown in Fig. 12 with resistances at R and RI.

The values can be calculated as follows: Deduct screen volts from maximum volts to determine the volts to be dropped in R. For example, 150 volts maximum, screen volts 80 = 70 volts to drop. Current is, say, ·7 m.a. The current flow through R is that taken by the valve plus that in the potentiometer, that is $(4 \times {\cdot}7) + {\cdot}7 = 3\frac{1}{2}$ m.a.

Therefore the resistance of R will be

$$\frac{70}{3{\cdot}5} \times 1{,}000 = 20{,}000 \text{ ohms.}$$

The volts to be dropped by RI will be the screen voltage, that is 80; the current is 2·8 m.a.—that is four times valve current. Therefore

$$\frac{80}{2{\cdot}8} \times 1{,}000 = 30{,}000 \text{ ohms.}$$

If it is desired to supply a variable voltage to the screen, a potentiometer can be substituted for the fixed resistance RI and should have the value calculated above or something very near it ; the skeleton circuit is shown in Fig. 13 and will be found adaptable to many practical circuits. A development of the same idea, with three separate voltage outputs, is shown in Fig. 14, with a potential divider across the main leads and equal topping points giving voltages of, say, 180 maximum, 135 at first tap, 90 at second tap.

Decoupling Resistances

These are introduced into circuits to offer a very high resistance to high frequency currents, and are employed in conjunction with a fixed condenser which offers relatively low resistance to such currents.

Consequently, the unwanted or used signal currents in, say, the anode circuit of a valve are prevented from flowing into the H.T. circuit as they have an easier path open to them through the condenser to earth, as in Fig. 15, where R is a coupling resistance and RI the decoupling resistance.

Pre-Set Resistances

The " Igranic " pre-set resistance has many practical uses. It enables the exact value of resistance to be adjusted to a nicety. It consists of a special wire winding on a porcelain former which can be mounted anywhere on the panel or baseboard, or on a metal chassis.

An adjustable finger contact regulates the amount of resistance in the circuit.

Available from 2 to 50 ohms. as a resistance and from 400 to 1,000 ohms as a potentiometer.

Dubilier Metallized Resistances

These are of the non-wire-wound type and serve the purpose of voltage dropping resistances, for providing tappings of various voltages in H.T. apparatus, for decoupling resistances in amplifiers, and for providing grid bias voltages, etc. The following table gives the maximum currents and voltages for different values of the 1-watt resistance.

Resistance Ohms.	Max. Current mA.	Max. Voltage.	Resistance Ohms.	Max. Current mA.	Max. Voltage.
100	100·0	10·0	20,000	7·3	142·0
250	62·5	16·0	25,000	6·4	160·0
500	45·5	22·0	30,000	5·8	175·0
1,000	31·0	30·0	40,000	5·0	202·0
1,500	26·0	37·0	50,000	4·6	227·0
2,000	23·0	44·0	75,000	3·6	277·0
2,500	20·5	49·0	100,000	3·3	315·0
5,000	14·5	71·0	150,000	2·6	370·0
7,000	12·0	84·0	200,000	2·3	440·0
9,000	10·5	95·0	250,000	2·05	490·0
10,000	10·0	100·0	300,000	1·9	540·0
15,000	8·4	120·0	400,000	1·6	630·0
17,500	7·7	132·0	500,000	1·4	700·0

Available also in values from quarter megohm up to 10 megohms for use as grid leaks.

Dubilier Sparking Plug Resistances

These are designed to reduce the interference arising from the sparking plugs and ignition system of cars. They are provided with a socket at one end to screw on to the terminal thread of the sparking plug.

Interchangeable Wire-wound Cartridge Type Resistance

The following table shows the current-carrying capacity for different values of resistances of the Ferranti cartridge resistance type W.

Resistance, in Ohms.	Current Carrying Capacity in Milliamps.	Resistance, in Ohms.	Current-Carrying-Capacity in Milliamps.
300	70	15,000	10
500	70	20,000	10
650	60	25,000	10
1,000	50	30,000	5
1,250	50	35,000	5
2,000	50	40,000	5
3,000	30	50,000	5
4,000	20	60,000	5
5,000	15	75,000	5
6,000	15	100,000	5
8,000	15		
10,000	10		

SERVICING

THE MCMICHAEL DUPLEX FOUR PORTABLE RECEIVER. SUITCASE "S" TYPE, AND CABINET "C" TYPE

Fig. 1.—HOW TO REMOVE CHASSIS OF THE DUPLEX FOUR SUITCASE (" S ") TYPE. FIRST OPERATION.
After removing battery panel in the usual way, take out both high tension battery and accumulator. Remove the eight raised head screws from the ebonite of the tuning panel.

ELECTRICAL DETAILS

CONSTANTS NOT INDICATED IN DIAGRAMS. (Figs. 9a and 19a). (Average values.)

FRAME AERIAL.—*Suitcase Type.*—Short wave side, 2·5 ohms ; long wave side (the whole winding, see diagram), 7 ohms.

FRAME AERIAL.—*Cabinet Type.*—Short wave side, 2·7 ohms ; long wave side (both windings), 7·5 ohms.

SCREENED GRID ANODE H.F. CHOKE. —*Both Types.*— 500 ohms.

H.F. TUNING COILS.—*Both Types.*— Short wave, 2·5 ohms ; long wave (combined coils), 17·5 ohms.

REACTION COIL.—*Both Types.*—1 ohm.

FIRST L.F. TRANSFORMER.—Step-up ratio, 1 : 3.

SECOND L.F. TRANSFORMER.—Step-up ratio, 1 : 3.

TOTAL HIGH-TENSION CONSUMPTION (at 120 volts), 8 milliamperes (average).

APPROXIMATE VOLTAGE ON SCREENED GRID ANODE (first valve), 118 volts.

APPROXIMATE VOLTAGE ON SCREEN OF H.F. VALVE (first valve), 45 volts.

APPROXIMATE VOLTAGE ON DETECTOR ANODE (second valve), 45 volts.

APPROXIMATE VOLTAGE ON FIRST L.F. VALVE (third valve), 116 volts.

Fig. 2.—REMOVING THE CHASSIS OF THE DUPLEX FOUR SUITCASE ("S") TYPE. Second OPERATION.

Place the fingers under the edge of the plated strip and lift gently for 1 inch.

Fig. 3.—THIRD OPERATION.

Run the fingers forward under the panel and tilt the chassis from the front. The robust nature of the fittings and the ease of access to the mechanism make the finding of mechanical trouble free from difficulty.

APPROXIMATE VOLTAGE ON OUTPUT VALVE (fourth valve), 112 volts.

(NOTE.—The high-tension voltages given here assume a high-tension battery voltage of 120 full and a high-resistance voltmeter, 1,000 ohms per volt type used, WITH THE VALVES IN POSITION AND SWITCHED ON.)

TESTING

For complete failure or substantially depreciated results, the instrument may be tested externally with the theoretical diagram and tabulated list of constants as a guide.

Where testing reveals a fault in a component, or it is desired to test separately the value of a separate item, reference should be made to the photographs for the simplest method of dismantling to approach the unit.

Testing should proceed in a logical manner.

(1) Try accumulator for voltage and specific gravity. Use one that is fully charged and reading 2 volts.

(2) Test high-tension battery for voltage *on load, i.e.*, after the set has been running for approximately five minutes and while it is still switched on.

(3) Test emission of the valves. This simply means the high-tension battery current flowing through each valve which, as given above, averages 8 milliamperes for the whole receiver.

If the current consumption is below 7 milliamperes, try other valves. The power valve itself takes approximately 6 milliamperes. The current consumption of the remainder is so small that substituting another valve is the only method of testing in the absence of a separate valve emission testing instrument.

(4) While the set is switched on and the milliammeter still in circuit, tap each valve in turn. Intermittent disconnections and intermittent short circuits will be revealed in the noise made in the loud speaker or the kicking of the milliampere needle. The two faults indicated are a source of fading, noises, and often complete failure.

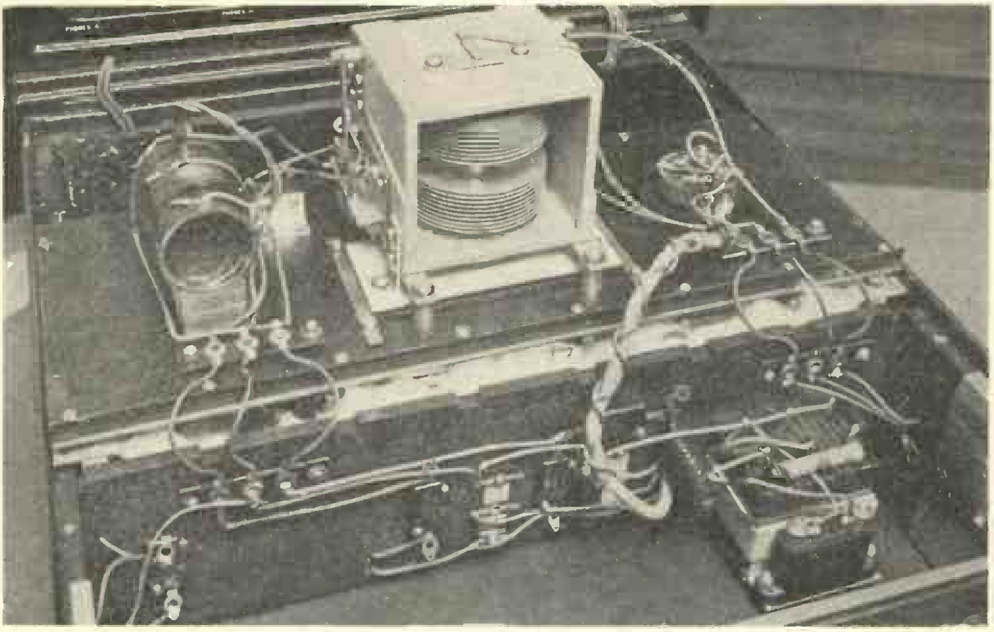


Fig. 4.—THE TUNING PANEL EXPOSED FOR TESTING.

After completing the operation shown in Fig. 3, tests can be made on the tuning panel before proceeding with the dismantling, as shown in Fig. 5.

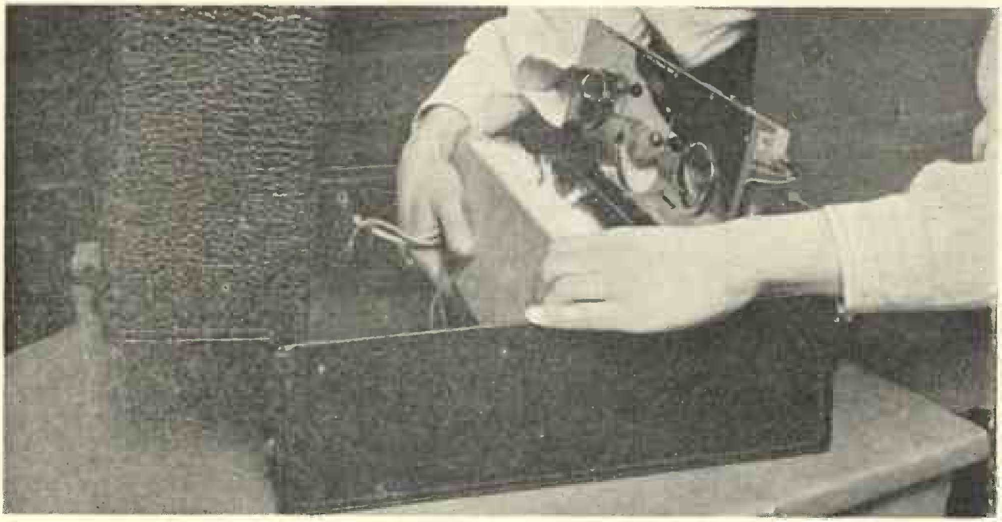


Fig. 5.—FOURTH OPERATION IN DISMANTLING RECEIVER.

To expose the remainder of the components (low-frequency transformers, valve holders, etc.), the valve compartment must be inverted. Remove the four countersunk screws passing through the aluminium at each end of the valve compartment. Take out the valves. Disconnect the three wires on the right of the well which pass through a hole in the right-hand side, connecting to the frame aerial, and also the two wires on the left of the well, passing to the loud speaker (not forgetting the earthing wire joining the front aluminium lining). Then, with the operating chassis resting on its edge, ease up the valve compartment as shown above.

(*Warning.*—If the set is tested out of the case, or partially so, it will probably be found unstable owing to the temporary ineffectiveness of the aluminium lining referred to in brackets above.)

The success of the last two tests depends upon there being no failure of continuity in the internal windings or resistances. Hence a valve known to be good and inserted into its correct socket failing to produce a deflection of the milliampere needle is a rough indication of a fault in that particular circuit.

The combination of the tabulated constants and the valve tests described will give a lead to the source of the trouble.

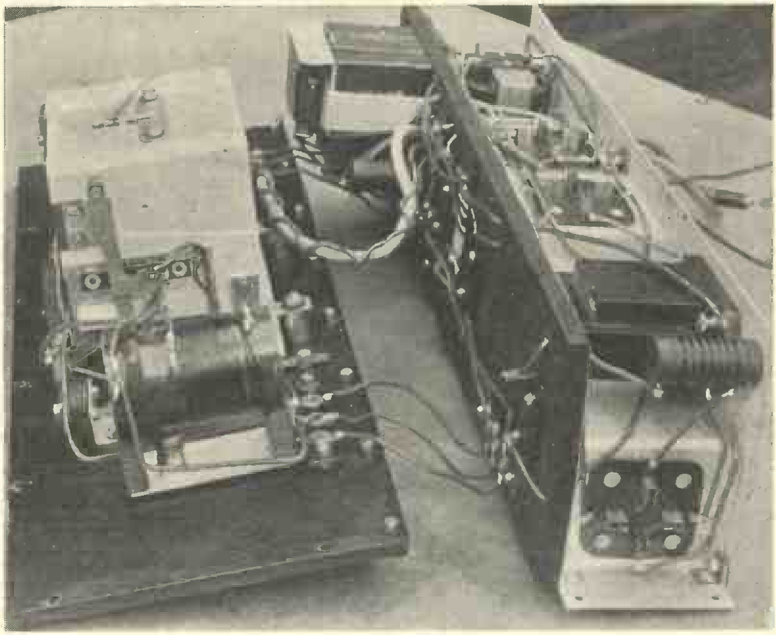


Fig. 6.—Final Position of Inverted Chassis and Valve Compartment.

The above are now free from the case. Tension of valve sockets may be examined and tests of low-frequency transformers for noises as described in the Electrical Details may be made. The operating panel and valve compartment are replaced by reversing the foregoing operations to this point.

Testing for Break in Continuity of Circuits

For example, inserting valve No. 3 and finding no deflection of the milliampere needle is a rough indication of a break in the continuity of the components associated with the third circuit. The valve should, therefore, be removed and a voltmeter used, the negative side of the voltmeter making contact with H.T. — plug, and the positive wire from the voltmeter inserted into the anode socket of the third valve holder. Reference to the theoretical diagram shows that to operate the voltmeter current should flow through the primary of the second low-frequency transformer.

What to do if no Voltage is Indicated

If no voltage is indicated, then the primary winding of the second L.F. transformer, the wire to the anode socket from the transformer or the wire from the transformer to the H.T. positive is disconnected. (It should be remembered that, since the full voltage is obtained upon this valve, the test does not indicate a short circuit of the ·001 parallel condenser in the cabinet model. This should be tested later, for such a breakdown is very rare.)

The correct deflection having been obtained, ascertain if the valve is receiving its current from the accumulator by taking the voltage across the filament sockets. A fruitful source of trouble is poor contact of the valve in the holder. The pins of the valve should be opened and the valve pushed in gently but firmly.

Taking advantage of the four sockets of each valve holder, continuity tests can be carried out, except where a fixed condenser is interposed, *i.e.*, in the case of the frame aerial, the H.F. tuning coils and the reaction coil. To test the three latter, see photographs on the section under consideration.

Fig. 7.—The Loud Speaker Compartment.
Remove the six oxidised screws, three on each side of the lid

Fig. 8.—Sixth Operation. Loud Speaker Compartment.

Insert the fingers between the leather and the moulded grille of the loud speaker to left and right, as shown. P· forward from the top, allowing the grille to lie inverted on the bottom portion of the instrument.

Fig. 9.—Seventh Operation. Loud Speaker Compartment.

To deal with the loud speaker cone or unit, remove the two protecting battens as shown. The loud speaker cone will come off after heating the solder on the apex. To remove the loud speaker unit from the grille, remove the two screws from the front of the grille.

UNDESIRABLE ELECTRICAL EFFECTS

This sub-section deals with a receiver which, while working, produces unsatisfactory results.

(1) Crackling Noises of Varying or Constant Intensity

These noises may be divided into three classes: (*a*) external origin; (*b*) caused by the accessories, batteries and valves; and (*c*) internal breakdown.

A rough test to differentiate between external (*a*) and accessory (*b*) plus (*c*) internal, may be made by turning down the volume control which reduces the sensitivity of the first valve. If the noises decrease in intensity, then they are usually due to (*a*). No change in intensity usually denotes a fault under (*b*) or (*c*).

Noises of External Origin

(*a*) Noises of an external origin are due to natural or artificially generated electricity. Having decided that the origin of the noise is external to the receiver, nothing can be done *to the receiver* to prevent their reception.

Noises due to Faulty Accessories

(*b*) A running down high tension battery or an old accumulator are fruitful sources of crackling noises. These units should be substituted one at a time.

A noisy valve may usually be traced by tapping it, as already described, or by substitution, see following paragraph for further confirmation.

Noises due to Internal Faults

(*c*) Assuming a blameless high tension battery and accumulator, both the internal fault under this sub-heading and a noisy valve may be found by removing the valves one by one, beginning, of course, with the screened-grid valve. At a point the noises will stop, indicating that the valve last removed is noisy or that there is a fault in that particular circuit. Eliminating the valve by the test already described, a pair of HIGH-RESISTANCE telephone receivers (say, 8,000-ohm type) are now useful in locating the source of the noise.

Testing a Circuit for Crackling Noises

Taking again the third valve, for example, after removal insert one pin of the head telephones in the anode socket, attach the other pin to H.T. negative plug. Current will now flow through the low-frequency transformer primary to the head telephones. If the primary winding is breaking down, crackling noises will be heard in the telephones, the fluctuations of current probably being too small to affect the needle of a meter.

Should the crackling noises be present, test back by removing the pin from the anode socket of the valve holder, and, on opening the receiver (see Photographs), place it upon the H.T. terminal of the L.F. transformer. Absence of crackling noises now will denote that the primary winding is on the point of breaking down. This test may be applied to valves 1, 2, 3 and 4, the latter, of course, covering the loud speaker windings themselves.

(NOTE.—Placing a pair of head tele-

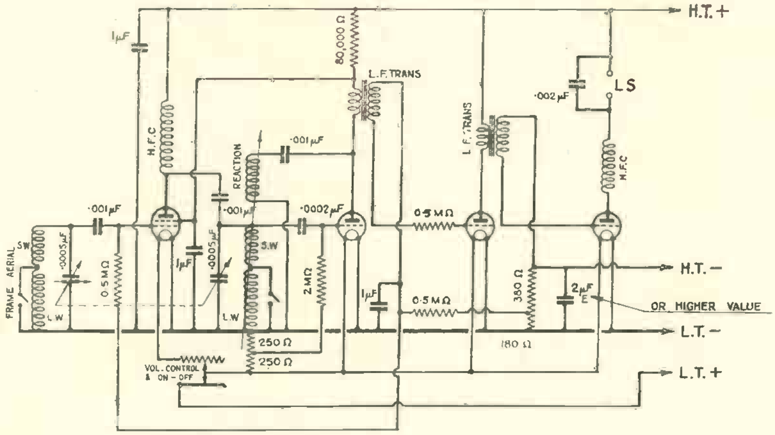


Fig. 9A.—THEORETICAL CIRCUIT DIAGRAM OF DUPLEX FOUR ("S") TYPE.

Fig. 10.—How to Remove the Chassis of the Duplex Four Cabinet (" C ") Type. First Operation.

After removing the back of the instrument, both high-tension battery and accumulator, remove the six countersunk screws holding the separator, which should be taken out.

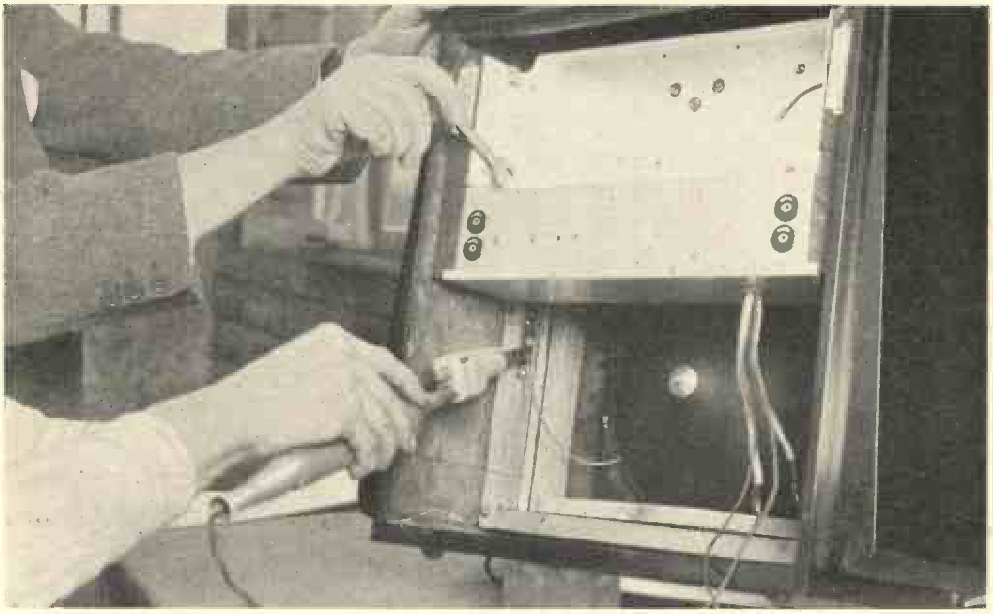


Fig. 11.—Second Operation.

The loud speaker unit is attached to the *cabinet.* Unsolder the two leads as shown above (lower portion), and after taking out the valves, remove the four chassis bolts (upper portion), two each end of valve platform.

phones directly across the high tension battery, as described in this paragraph, causes a comparatively substantial current to flow through the windings. Unless they are, therefore, of the high-resistance type, as described above, a resistance of 5,000 to 10,000 ohms should be placed in series with the telephones to protect the windings. This resistance, however, must be blameless so far as continuity and contact are concerned, otherwise the test will be futile.)

(2) Microphonics

Acoustic reaction or microphonics are invariably due to one of the valves, since the values of this receiver have already been adjusted to avoid resonance effects.

The offending valve may usually be found by tapping each in turn with the finger nail when the set is switched on.

(3) Distortion

Firstly, adjust the loud speaker diaphragm by means of a coin or a small screwdriver. The unit is of the balanced armature type. Mechanical contact with the poles of the magnet can, therefore, be obtained by a clockwise and anti-clockwise movement. The position approximately half-way between the poles of the magnet is correct for absence of rattle.

Secondly, since the reproduction of both these instruments is controlled by automatic grid bias, the power valve recommended in the instructions for working only should be used. This point should be checked and another valve substituted. No cure may indicate a breakdown of the 560-ohm (380 + 180) bias resistance which can be checked for continuity by testing between H.T. negative and L.T. negative between which it is connected. Bear in mind the warning given under Mechanical Details with regard to the electrolytic condenser. The loud speaker itself may be tested only by a substitution, as described.

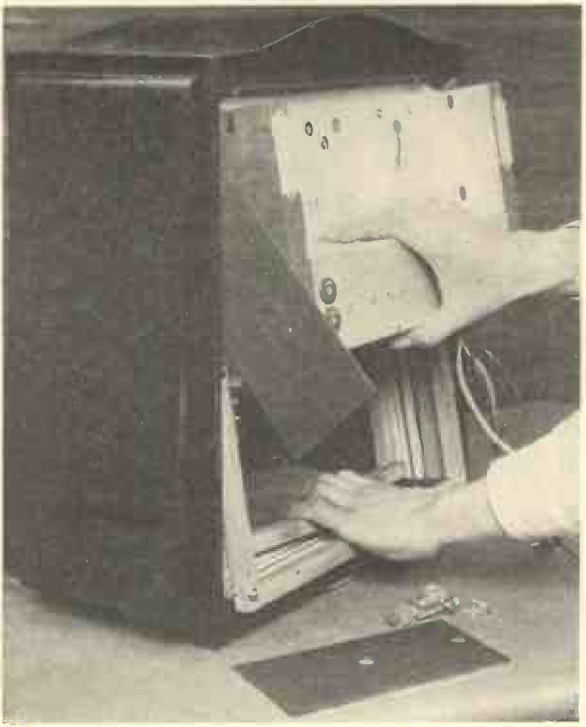


Fig. 12.—Third Operation.

The chassis and frame aerial should now be eased forward, taking the bottom of the frame aerial a little ahead of the remainder in order to clear the beading on the inside top of the cabinet. Observe the fibre packing pieces which are used between the chassis and the cabinet at the top.

Note.—When replacing chassis, the cranks of the operating controls should be set to coincide with the position of the paxolin operating cranks which are left behind the front of the cabinet. When nearly in, the chassis should be teased into position so that the spigots may engage the slots. Failure to obtain correct alignment may result in a faulty movement of the volume and reaction controls, or failure to operate altogether.

MECHANICAL DETAILS OF THE McMICHAEL DUPLEX FOUR (SUIT-CASE "S" TYPE)

In Fig. 4 the tuning panel is shown inverted, showing the method of testing resistance and continuity of H.F. coils. Test flat solenoid winding for the short wave and across the whole—flat solenoid plus the piled honeycomb—for the long wave, bearing in mind that the switch must be set to "Long."

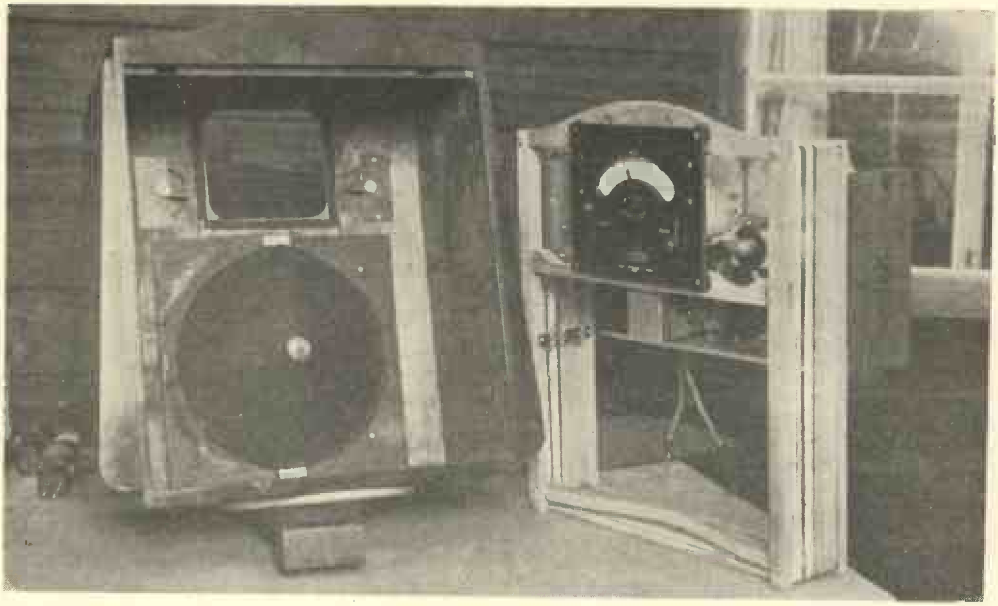


Fig. 13.—The Chassis Removed.

The complete instrument is shown removed from the cabinet, leaving only the loud speaker and the cranks at the back of the operating controls to the left and right of the panel aperture.

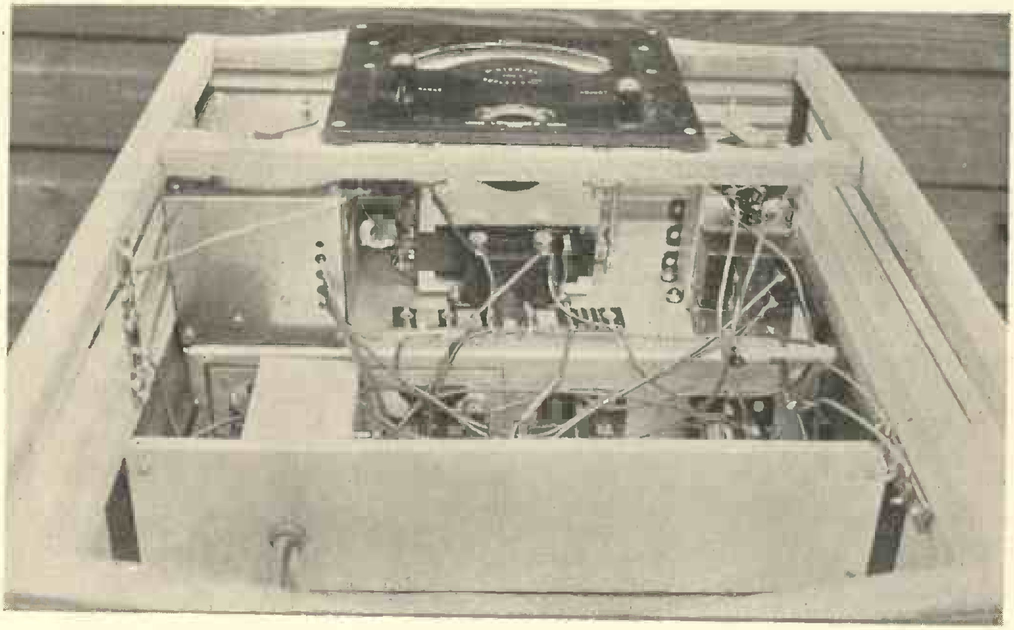


Fig. 14.—The Chassis Ready for Testing Components.

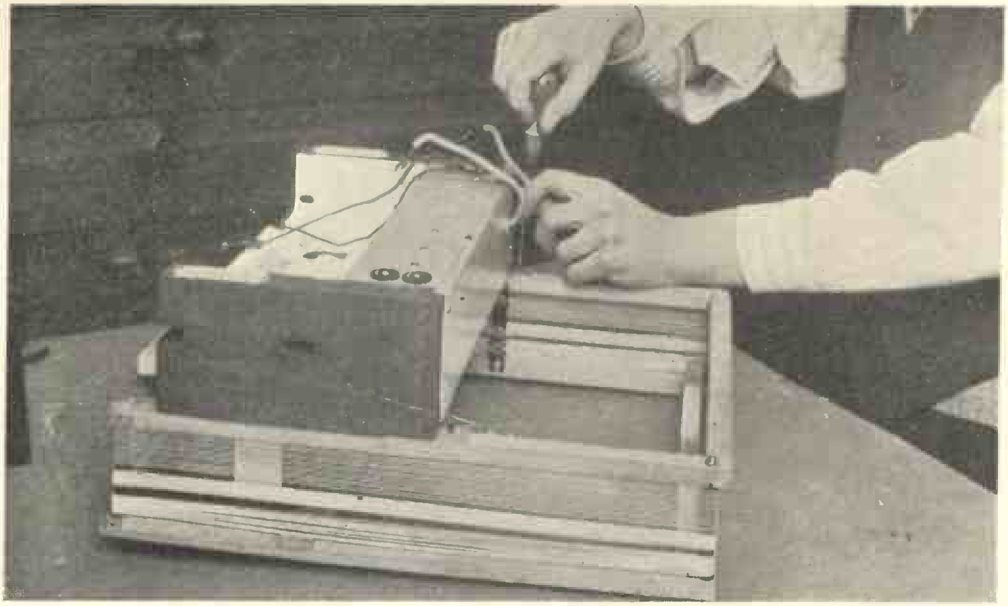


Fig. 15.—Fourth Operation.

The indicator panel and variable condenser are mounted upon the frame aerial members. To remove the frame aerial with the variable condenser, first disconnect the five wires between the variable condenser and coil box, and one attached to the tab on the rocking section of the variable condenser, with the chassis lying on its back as in the previous figure.

The wire running from the earthing tab on the coil box down to the lower tab of the small circular trimmer condenser and then underneath the aluminium condenser casing, must be taken off from the earthing tab and loosened from the circular trimmer condenser. The wire from the top tab of the circular trimmer condenser must be loosened from that tab, and also the pin of the coil box to which it proceeds.

The frame aerial eyeletted tabs on the left and the loud speaker tabs on the right should now be unsoldered. Turning the chassis face down as in Fig. 15 above, remove the four screws which hold the instrument portion to the back frame members.

The flexible wire emerging from the coil former between the two windings connects up with the reaction coil, and can be tested for continuity across the two left-hand eyeletted tabs.

In testing the frame aerial resistance on the right, the short wave winding lies between the middle and right-hand eyeletted tabs and the long wave winding across the two outer eyeletted tabs.

The effectiveness of the switch may also be checked at this point by leaving the ohm-meter across the whole winding of the H.F. coil, and, secondly, across the whole of the frame aerial, while the wave-change switch is operated.

The tuning panel can be removed from the remainder by disconnecting the three wires on the left and the six wires on the right.

Fig. 4 also shows the group of condensers, resistances and chokes in the well. Before testing these components for capacity, resistance, leak or short circuit, the valves should be removed from the valve compartment.

(Warning.—The small electrolytic condenser mounted at the front of the right condenser bank has a positive and negative terminal. When testing for leak or short circuit, therefore, the positive and negative wires attached to the galvanometer and battery must be correctly joined, and the connections removed from the condenser itself.

These condensers always show a slight leakage, but do not be deceived by the substantial deflection obtained if connected the wrong way. The capacity of this condenser is not important, for values

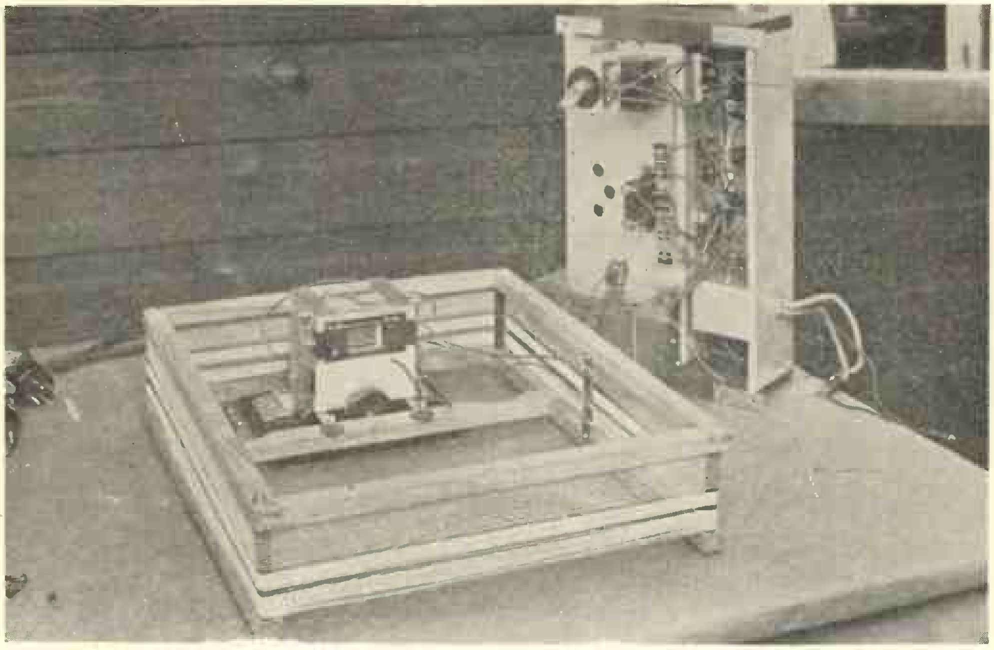


Fig. 16.—The Final Stages of Dismantling

The instrument portion is now separated from the frame aerial and the complete variable condenser unit. Further dismantling requires no explanation for the holding-down bolts are visible and accessible.

Access to valve-pin sockets and transformers, if necessary, may be obtained by loosening the bottom plate through which pass the battery leads.

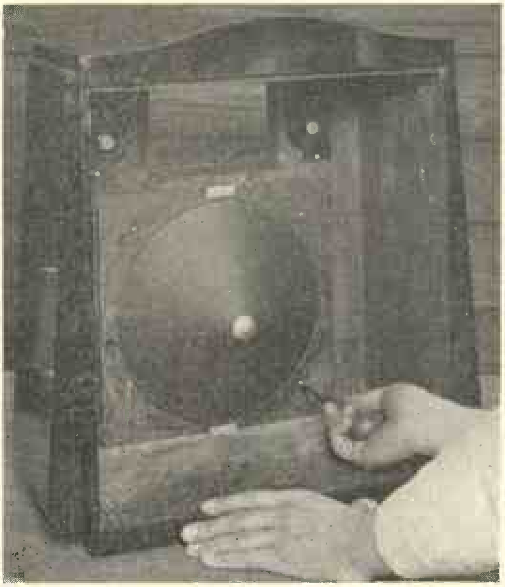


Fig. 17.—Fifth Operation. Loud Speaker Compartment.

Take out the four countersunk wood screws at the back of the grille, when the grille itself will come away, complete with loud speaker and cone.

Fig. 18.—Sixth Operation. Loud Speaker Compartment.

The cone can then be removed by unsoldering the apex from the driving rod and lifting off, revealing the loud speaker unit mounted upon a metal support.

are used as convenient in production.)

The loud speaker leads are on the left-hand side of the well connected across the ·002 fixed condenser.

TESTING COMPONENTS OF CABINET "C" TYPE

This is done with the chassis lying on its back, as in Fig. 14. The frame aerial windings finish off at the eyeletted tabs attached to a paxolin strip on the left-hand side. The effectiveness of the range change switch, the continuity and resistance of the frame windings may be taken, short wave side across the lower and middle tabs, long wave side across the top and bottom tabs.

The ·0002 detector grid condenser is inside the coil box. To test the continuity and resistance of the H.F. coils, contact to the meter should be made from the screening box itself (which is earthed) and the top tab of the small circular trimmer condenser mounted on the right-hand side of the coil box. This amounts to testing straight across the variable condenser (see theoretical diagram).

The range switch should now be operated to open and close the long wave portion of the H.F. coil.

All components may now be tested electrically and separately.

The electrolytic condenser across the automatic grid bias resistance is mounted in this case between the variable condenser and the two flat wire-wound resistances. See warning note on Page 422 of suitcase type, with reference to testing this condenser.

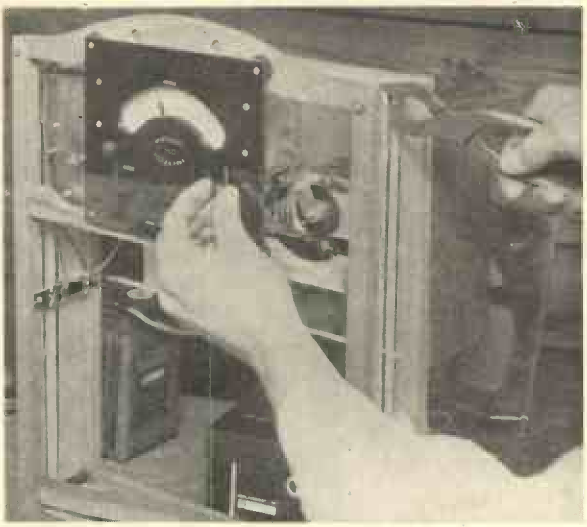


Fig. 19.—Rematching Tuning by Altering Spacing of the Frame Aerial Windings.

REMATCHING TUNING BY ALTERING SPACING OF FRAME WINDINGS, ETC. (see Fig. 19)

This applies to both suitcase ("S") type and the cabinet ("C") type, and should be carried out with the chassis removed from its cabinet, as in Fig. 14.

(Note.—To test, use a separate loud speaker, or connect long wires from the chassis into the loud speaker attached to the cabinet.)

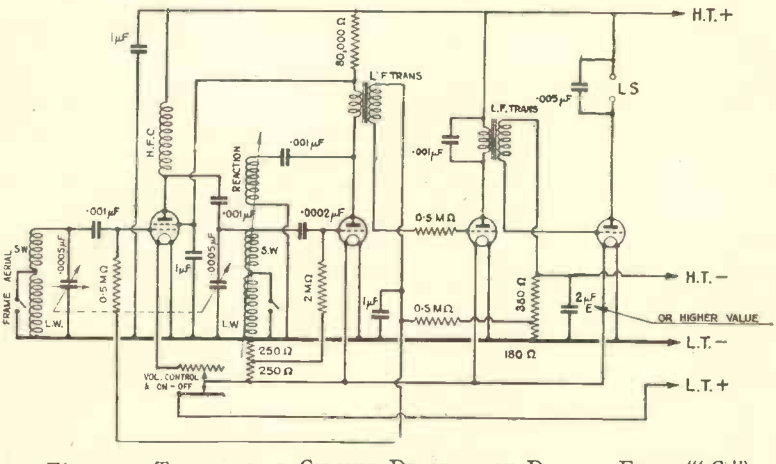


Fig. 19a.—Theoretical Circuit Diagram of Duplex Four ("C") Receiver.

Tuning Coils

The small trimming condenser which in the case of the cabinet model is mounted upon the side of the H.F. tuning box, and in the suitcase model mounted near the tuning coil on an aluminium bracket, is used to balance the self-capacities of the frame and coils, because of the widely differing type of windings.

At the factory the trimmer is adjusted to bring the matching as near as possible to the centre of the " Adjust " travel, consistent with correctness of tuning, both the effects being of consequence at the bottom of the tuning scale only.

(Note that while the trimmer is across both long and short wave coils in the type "C" model, it is only across the short wave coil in the type " S.")

Incorrect matching below 350 metres indicates unbalance of the self-capacities, and requires correction by means of the trimmer condenser. Should it be found that the " Adjust " control has to be pushed right to the top of its operating slot and still the instrument is not quite in tune, then it indicates that the high-frequency side is to blame and the trimmer condenser must be loosened very slightly to bring that circuit down into tune firstly with the " Adjust " knob at its present high setting, and then a little lower to cause the " adjust " knob to follow it to the middle of the slot.

If the " Adjust " control fails to tune at the lower end of the slot, the trimmer condenser must be *screwed up*.

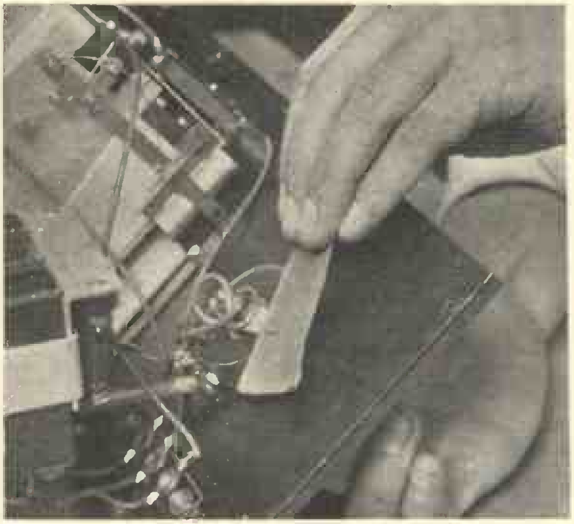


Fig. 20.—Removing Noises from Volume Control. Both Suitcase ("S") and Cabinet (" C ") Types.

The volume control consists of a combined switch rheostat.

The above shows the method of cleaning the edge of the brass segment and the contact arm.

The long switch arm on the left of the variable condenser casing should be cleaned, if necessary, in the same way.

As a rule, however, the high-frequency circuit may be regarded as the *tuning constant*, and this little circular trimmer condenser may be left alone.

Tuning Frame Aerial. Short Wave

On the other hand, however, should the matching be found to be satisfactory at the lower end of the short wave tuning scale, but gradually going out of step as the top end of the scale is reached, then this indicates that the frame aerial is unbalanced. Incorrect matching in this case is also indicated by the inability to obtain the tune point of a distant station upon the right-hand " Adjust " knob, which protrudes through the working panel.

As the adjust knob is dropped to the bottom of the slot the capacity *decreases*. Choose a distant signal and observe if the knob is lifted or dropped to bring it better into tune. This will indicate in which direction better matching lies.

Observe that the ebonite cross pieces supporting the frame windings are threaded to take the short wave aerial. Rotating any one of these pillars will alter the position of the short wave aerial relative to the long wave aerial.

It will be noted that to receive short waves the long wave aerial is short-circuited (see theoreticals figs. 9a and 19a). If the short wave aerial is moved nearer to the long wave aerial, the inductance of the former is *decreased*, owing to the

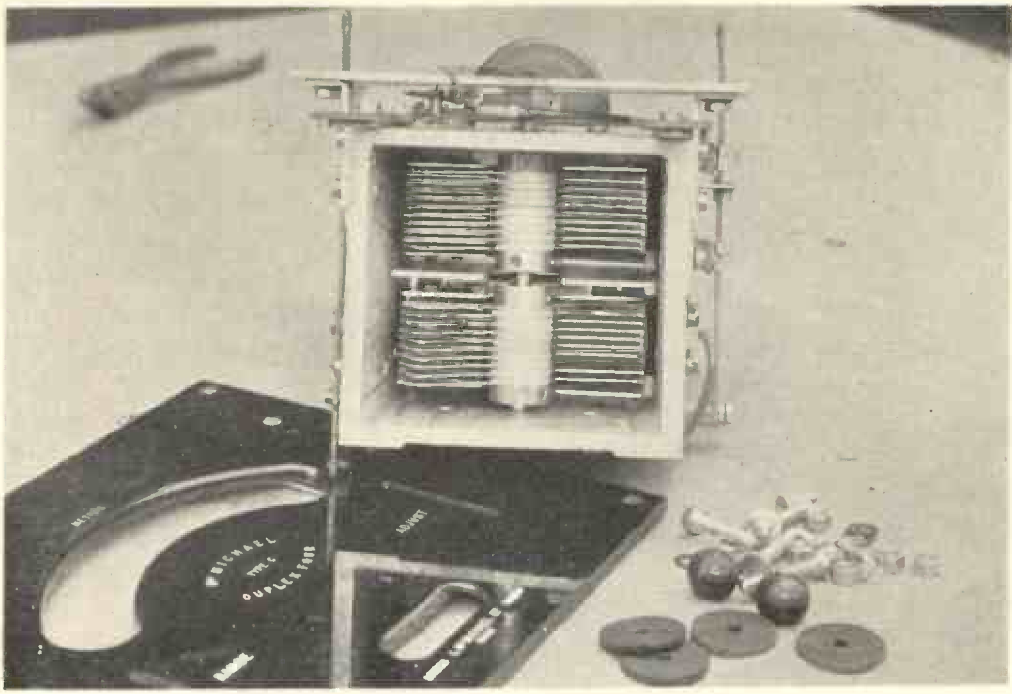


Fig. 21.—DETAILS OF THE GANG CONDENSER.

The above shows the Duplex gang condenser in its die-casting. This has been removed from the frame aerial members shown in Fig. 16, firstly by unscrewing the two small knobs marked " range " and " adjust," and then by removing the four fastening nuts at the back of the frame aerial members and the tuning panel from the front. On no account should the grub screws holding the fixed vanes (adjacent to the screen separating the two halves of the condenser) be removed.

absorption effect of the closed long wave aerial. Moving the short wave aerial away from the long wave aerial reduces the absorption effect and, therefore, *increases* the inductance.

When the " Adjust " knob fails to match at the *bottom* of the slot, then close the aerials, and *vice versâ*.

Briefly stated, when the position of the " Adjust " knob is as shown below on the left, and the station is coming into tune, but is not quite covered, then carry out the operation shown on the right, *i.e.*,

BOTTOM = CLOSE AERIALS,
TOP = OPEN AERIALS,

after which lock the ebonite supporting pieces by tightening up the side nuts to grip the wooden frame.

When the matching experiment is carried out on a distant station the cranks of the volume and reaction controls may be safely operated with the fingers.

Tuning Frame Aerial. Long Wave

The LONG WAVE aerial must be treated as a single inductance, because (see theoretical diagram) all the winding is in use, and, therefore, the absorption notes above do not apply. If the long wave aerial windings are pushed up together, the inductance is *increased* and *vice versâ*.

On the left below we give the position of the " Adjust " knob, which calls for the operation shown opposite it upon the right, as follows :—

BOTTOM = OPEN LONG WAVE AERIAL.
TOP = CLOSE LONG WAVE AERIAL.

WARNING.—On no account must the relative position of the short wave frame and long wave frame be altered when attending to the *long wave tune*. The long wave windings only must be bunched or opened, or it will throw out the matching on the short wave side, as mentioned earlier.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION III—ALTERNATING CURRENTS OF RADIO FREQUENCY — CONVERTING WAVELENGTHS INTO FREQUENCIES

WE have been dealing with alternating currents of frequencies up to 100 cycles per second. These frequencies are called POWER FREQUENCIES because they are used for electric power supplies. Wireless signals are also composed of alternating currents and voltages, but in this case the frequency is very much greater than power frequencies. Imagine the sequence of events in a complete cycle being speeded up so that instead of fifty complete cycles occurring in one second as many as 500,000 occur—*i.e.*, 10,000 times as many. Thus one complete cycle occupies not $\frac{1}{50}$th of a second but $\frac{1}{500000}$th of a second, a time so short that it is almost impossible to realise what it means. Suppose that we started to count from 1 up to 500,000 at the rate of one per second without stopping for food or sleep. It would take us nearly six whole days of twenty hours apiece to reach the half million. Now try to imagine that all this could happen in one second, and we get a vague idea of how quickly the current in a wireless transmitter or receiver can alternate.

Radio Frequencies

The frequencies of wireless signals are called RADIO FREQUENCIES; they vary from about 10,000 cycles per second to well over 1,000,000,000 cycles per second. The mathematician has a shorthand way of writing large numbers like these. He counts the number of noughts in the number and in place of 1,000,000,000 would write 10^9. The small number 9 at the top of the 10 is called an INDEX, and 10^9 means 10 multiplied by itself for 9 times. That is to say, a number 1 followed by 9 noughts. Thus 10^6 means $10 \times 10 \times 10 \times 10 \times 10 \times 10$, the answer being one million (1,000,000). If we want to write a number like 1,500,000—*i.e.*, one and a half million—we write it in this way: $1{\cdot}5 \times 10^6$—*i.e.*, 1·5 multiplied by one million, viz., 1,500,000. We shall constantly be using this abbreviation to save writing out large numbers, also another abbreviation for very small numbers. The number ·000005 means 5 divided by one million (1,000,000).

We could write this another way, viz., $\frac{5}{1000000}$, but this is even more awkward than ·000005. We have just used 10^6 as a shorthand for 1,000,000: let us use it again and write $\frac{5}{10^6}$. This is quite brief, but the mathematician does not even use the fraction line, he brings the 10^6 into the top line or numerator, and in order to distinguish it from 5×10^6 (which is

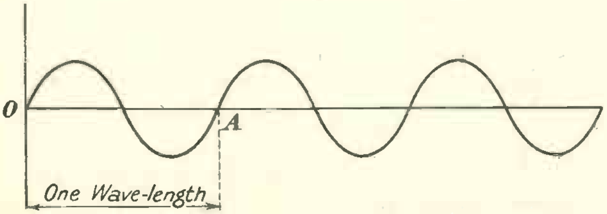


Fig. 1.—THIS DIAGRAM SHOWS THREE COMPLETE WAVES.
One wave is formed each time the electrons in the transmitting aerial go through a complete cycle of alternation.

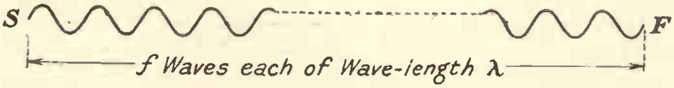


Fig. 2.—DIAGRAM SHOWING VELOCITY OF WAVES.

S is the source of waves, each of wavelength λ, there being f waves produced per second.

5,000,000) he places a — sign in front of the index, thus ·000005 = 5×10^{-6}.

(NOTE.—The expression 10^8 put into words is spoken this way: "ten to the eighth," or "ten to the eighth power." Similarly, 5×10^{-6} is "five times ten to the minus six.")

Kilocycles

Most readers are aware that we often refer to wireless signals by their frequency as well as by their wavelength. Thus the London Regional station has a frequency of 843,000 cycles per second, and also a wavelength of 356 metres. Instead of saying 843,000 cycles per second we can use the term "kilocycles per second." The prefix "kilo-" means "thousands of," thus 843 kilocycles per second means 843 thousands of cycles per second. The abbreviation kc/s. is used for kilocycles per second. The term "kilohertz" is coming into use; it is used for the whole phrase "kilocycles per second," one hertz being one cycle per second. The abbreviation for this is kh.

Wireless Waves

What is a wireless wave? At the transmitter the transmitting circuit — which we shall consider later — is connected to the aerial. One of the properties of an aerial is that it causes some of the alternating current, which passes to it from the transmitting circuit, to be converted into wireless waves. The well known analogy of a stone dropped into a pool of water and producing ripples on the surface of the water gives a useful idea of what a wave might look like if only it were visible to the human eye. The waves are actually set up by the very rapid to-and-fro motions of the electrons which constitute the current in the aerial. They surge backwards and forwards at the frequency of the current and the waves are sent out—or RADIATED—in all directions. (Special aerials, such as those used at the Post Office Beam Stations, concentrate the waves in a beam and in these cases radiation occurs in one direction only.)

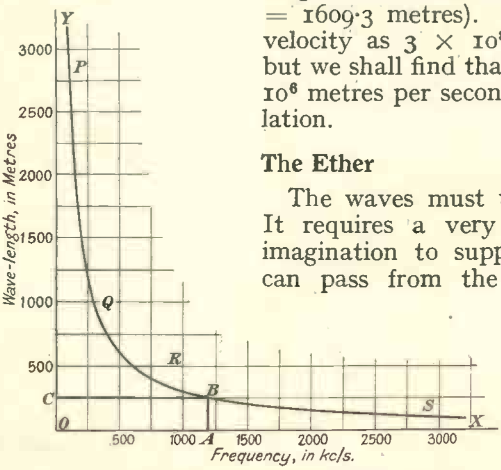


Fig. 3.—GRAPH FOR CONVERTING WAVELENGTHS INTO FREQUENCIES AND *vice versâ* WHEN THEY OCCUR IN THE REGIONS AROUND Q AND R.

Speed of Wireless Waves

The waves travel outwards at a very high speed, in fact they travel at the speed of light, viz.: 186,000 miles per second. Thus in $\frac{1}{10}$th of a second the waves travel $\frac{1}{10}$th of 186,000 miles, *i.e.*, 18,600 miles, or nearly round the earth. When we calculate the wavelength of a broadcasting station we always give the answer in *metres* and so we must convert the speed (the mathematician uses the term VELOCITY in place of speed) from *miles per second* into *metres per second.* We find that the velocity works out to 300,000,000 metres per second, which we shall write as 300×10^6 metres per second (1 mile = 1609·3 metres). We could write this velocity as 3×10^8 metres per second, but we shall find that writing it as 300×10^6 metres per second will simplify calculation.

The Ether

The waves must travel on something. It requires a very big stretch of the imagination to suppose that the waves can pass from the transmitter to the receiver without a something (called a MEDIUM) on which to travel, and although mathematicians can imagine a "nothingness" on which waves may "travel," we shall suppose that they travel on a medium called the ETHER. We cannot see or feel this ether, in fact we are only aware of it by means of such indirect effects as listening to a wireless programme. We assume that, whatever it is, it enables wireless waves (and light waves, X-rays, and other waves of a similar type) to travel from one place to another at the enormous velocity of 186,000 miles per second, or 300×10^6 metres per second.

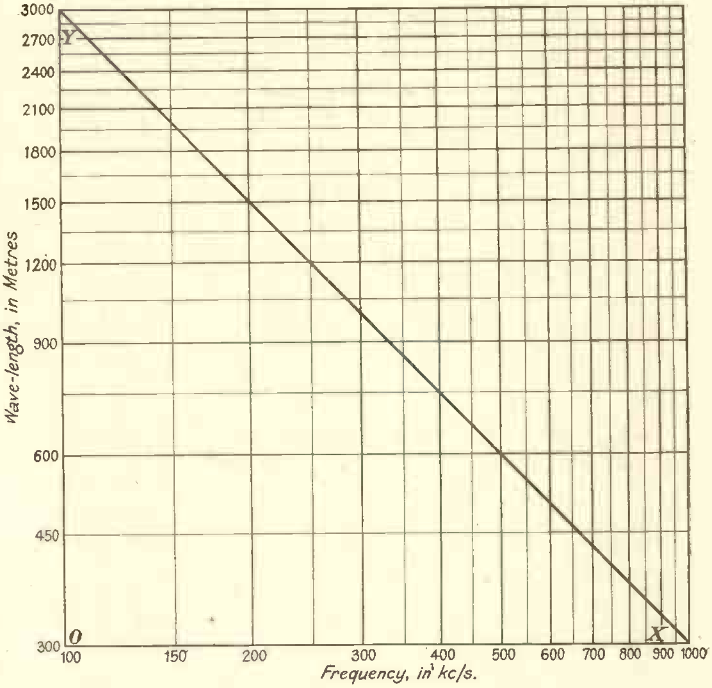


Fig. 4.—AN EXAMPLE OF A LOGARITHMIC GRAPH.

Here it will be seen that the graph is a straight line and it is now much easier to convert wavelengths into frequencies and *vice versâ* at any part of the scale.

Wavelengths

One wave is formed each time the electrons in the transmitting aerial go through a complete cycle of alternation. Thus the number of waves created in one second is equal to the frequency of the current in the aerial. In two seconds twice this number of waves is created, and so on. We can make a diagram representing a wireless wave—or one part of it—and Fig. 1 shows three complete waves. The shape of each wave is similar to the shape of the alternating current graphs in Figs. 3, 4 and 5, on pp. 358 and 359, and a sine wave equation represents the wave; as before, it is known by the name sine wave, and the mathematician uses the same terms in referring to this wave as he uses for the alternating current wave. The length from O to A, along the axis, is called a WAVELENGTH and the symbol used for wavelength is the Greek letter "λ" pronounced "*lambda.*"

Velocity of the Waves

Now the velocity of the waves is the distance that the waves travel in one second, and in one second there are as many complete waves produced as the number of complete cycles (*i.e.*, the frequency) of the current in the aerial. If each wave is λ metres long, then $\lambda \times$ (the number of waves in one second) is the distance the first wave has travelled in a second—*i.e.*, the velocity. In Fig. 2 S is a source of waves, each of wavelength λ, there being f waves produced per second. F is the point reached by one particular wave one second after it left the source. Thus the distance SF is occupied by f waves each of length λ, *i.e.*, SF $= f \times \lambda$. Therefore the velocity of the waves is $f \times \lambda$ metres in each second.

i.e., Velocity (V) = Frequency (f) $\times$ Wavelength (λ).

i.e., V (metres per sec.) $= f$ (cycles per sec.) $\times \lambda$ (metres)

or $$V = f\lambda \quad . \quad (1)$$

Converting Wavelength into Frequency

The f of equation (1) is the frequency of the wireless signal to which we have already referred. Equation (1) shows us how to convert from wavelengths into frequencies, and *vice versâ*, because the frequency multiplied by the wavelength is always equal to 300×10^6. (Whatever the wavelength the waves always travel at the same velocity.)

Example.—Suppose that we wish to convert a wavelength of 600 metres into frequency, we have :—

V (metres per sec.) = f (cycles per sec.) $\times$ λ (metres), and writing in the two values which we know, viz., V and λ, we have :—

$300 \times 10^6 = f$ (cycles per sec.) $\times$ 600
i.e., 600 times f equals 300 times a million. It is quite easy to see that f equals half a million cycles per second.

i.e., f = 500,000 cycles per second.
or f = 500 kc/s., or 500 kh.

Using equation (6) we can draw up a table showing wavelengths in one column and the corresponding frequencies in a second column, thus :—

Wavelength (metres).	Frequency (kc/s).
3,000	100
2,000	150
1,500	200
1,200	250
1,000	300
750	400
600	500
500	600
400	750
300	1,000
250	1,200
200	1,500
150	2,000
100	3,000

The table is incomplete, and in order to complete it we should have to enlarge it very considerably. Even if we increase the wavelengths by 1 metre at a time the table is still far from complete, and thus we must find a more convenient form of conversion chart.

In Fig. 3 wavelengths are measured along OY, and frequencies along OX. The curved line PQRS represents all the points corresponding to the wavelength and frequency figures in the table, and it has the advantage that intermediate values can be seen at a glance. As an example of the use of the graph let us convert the frequency of 1,200 kc/s. into a wavelength. The vertical line AB corresponds to the frequency we are converting, and it meets the curve PQRS at the point B. The horizontal line through B is BC, and this line corresponds to a wavelength of 250 metres. Thus we have converted from a frequency of 1,200 kc/s. to a wavelength of 250 metres.

The graph of Fig. 3 is most useful for converting wavelengths into frequencies, and *vice versâ*, when these occur in the ranges corresponding to the regions around Q and R on the curve. In the regions around P and S the wavelengths and frequencies are so crowded together due to the oblique slope of the graph that it is very difficult to read values accurately. Can we remedy this so that the graph is equally clear for the whole of its length ? Look at Fig. 4. The graph is a straight line, but notice that the divisions along the axes OX and OY are not evenly spaced. Near to O the divisions are a big distance apart, and as the distance from O increases the intervals on the axes decrease. That is to say, the SCALE of values along both axes changes. In previous cases the scales have been regular—*i.e.*, the divisons equally spaced.

Logarithmic Scale

The scale of Fig. 4 is called a LOGARITHMIC SCALE because the divisions along the axes correspond to the LOGARITHMS of the numbers instead of corresponding directly to the numbers themselves. Perhaps you do not know what a logarithm is ? The logarithms of which we are speaking are a system of numbers which help us to calculate. They change difficult multiplication and division sums into simple addition and subtraction sums. We have no time or space here to discuss logarithms, and readers who cannot use a log. table should read the chapter dealing with logarithms in Ralph Stranger's *Mathematics of Wireless*, or the section on logarithms in a good arithmetic book.

Why the Divisions on the Axes are not Evenly Spaced

The following table shows why the divisions on the axes of Fig. 4 are not evenly spaced. Column one is a list of actual numbers and column two gives the logarithms of these numbers. The numbers in column one increase regularly one at a time and correspond to the regularly spaced scale, but in column two they increase quickly at first and then more slowly and correspond to the logarithmically graded scale.

Number.	Logarithm of the Number.
1	0·0000
2	0·3010
3	0·4771
4	0·6021
5	0·6990
6	0·7782
7	0·8451
8	0·9031
9	0·9542
10	1·0000

Advantages of a Logarithmic Scale

Now look at the following table. What do you notice about it? Well, starting from 3 metres, which is equal to a frequency of 10^5 kc/s., as we *multiply* λ by 10, so we must *divide* f by 10.

λ (metres).	f (kc/s).
3	10^5
30	10^4
300	10^3
3,000	10^2
30,000	10^1 (= 10)

Fig. 4 is a conversion chart for wavelengths lying in the range from 300 to 3,000 metres. Suppose that we wish to convert a wavelength lying in some other part of the wavelength scale, do we require a separate chart? The advantage of the logarithmic scale is that we can use the one graph. All we have to do is to multiply or divide the wavelength or frequency by 10 as many times as necessary in order to bring it within the wavelength or frequency range of the graph, and then to multiply or divide the corresponding value, read from the graph, by 10 for the same number of times.

An Example

As an example, consider the conversion of a wavelength of 15 metres. In order to bring it into the 300 to 3,000 metres range we must multiply it by 10 × 10 (*i.e.*, by 100). From the graph we see that the wavelength of 1,500 metres is equivalent to a frequency of 200 kc/s., hence the wavelength of 15 metres is equivalent to a frequency of 100 × 200 kc/s., viz., 20,000 kc/s. We might write this answer as 2×10^4 kc/s.

QUESTIONS AND ANSWERS

Over what range do Radio Frequencies vary?

From about 10,000 cycles per second to well over 1,000,000,000 cycles per second.

At what speed do Wireless Waves travel?

186,000 miles per second. Thus in $\frac{1}{10}$th of a second the waves travel $\frac{1}{10}$th of 186,000 miles, *i.e.*, 18,600 miles or nearly round the earth.

What is the meaning of 10^6?

This expression reads "ten to the sixth," and means 10 × 10 × 10 × 10 × 10 × 10, *i.e.*, 1,000,000.

What is the meaning of 10^{-6}?

This expression is the same as $\frac{1}{10^6}$, *i.e.*, $\frac{1}{1,000,000}$ or one-millionth.

What is a Logarithmic Scale?

This is a scale in which the divisions along the axes correspond to the logarithms of the numbers instead of corresponding directly to the numbers themselves.

THE MAGNETIC PROPERTIES OF IRON AND KINDRED ALLOYS

NOTES ON THEIR USES IN WIRELESS

By L. D. MACGREGOR

EVERYONE is aware of magnetism and its general effects, but it is not so widely known to what extent it has been developed and the use to which such knowledge has been put.

A FEW ELEMENTARY CONSIDERATIONS

It is well known that if a coil of wire be wound round a piece of iron rod and a current be passed through the coil that the iron will become magnetised. Obviously the energy which produces this effect is from the current in the coil of wire and may be called the *Magnetising Force*. It will be found by experiment that the magnetism will vary according to the number of turns round the iron and the current through the turns, and that there is a relationship between the turns, the current through them and the magnetising force. To this magnetising force the symbol H has been given, and various units are used to express the amount of this force, the most common of which is *Ampere Turns*. These are taken per unit length of a coil or solenoid, and H is taken as being equal to $\frac{4 \times \pi}{10}$ times the number of amperes flowing in the coil times the number of turns per centimetre length of the coil.

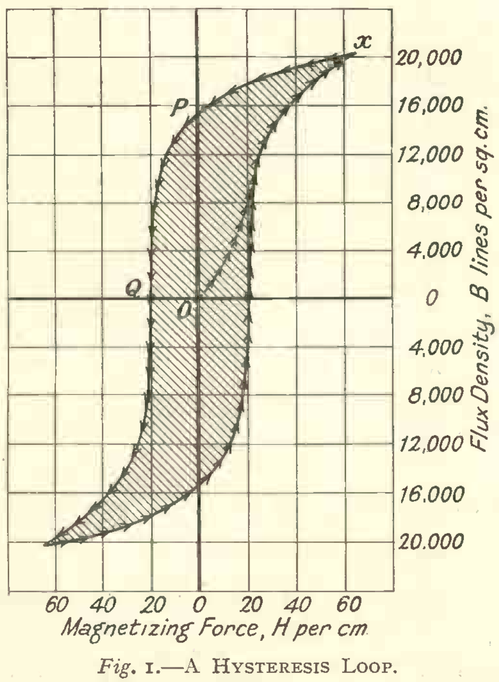


Fig. 1.—A HYSTERESIS LOOP.

This is a graph showing the relationship between the magnetising force and the flux density.

Magnetic Force or Flux

Now our coil of wire round the piece of iron will, when current flows through it, exert a magnetising force upon the iron, and lines of magnetic force or flux, as they are commonly called, will start at one end of the iron, travel through space to the other end and return back to the point of start. The end at which the lines of force start is generally known as the North Pole of the magnet, the other end is known as the South Pole, and the path of the lines is obviously the route taken by them producing a field or area acted on by the lines round the magnet, in three dimensions.

Flux Density

This flux will naturally be more dense the greater the amount of magnetism in the iron, and it is customary to represent the flux density by the symbol B. This flux density B is equal to the numerical value of the lines of magnetic force or flux per square centimetre.

Permeability

If we check the number of lines of force issuing from our piece of iron and then remove it carefully from the core of the coil we shall find that there are still lines of force issuing from the coil, but not so many as was the case when the iron was in the core of the coil. Obviously the iron is a very much better "conductor" of lines of magnetic force than the air which now occupies the core of the coil. This property of conducting lines of magnetic force is known as Permeability, and to it is given the symbol μ (pronounced "mew"). The conducting property or permeability of air is taken as a standard and considered to be equal to 1.

How these Three Properties are Linked up

It has been found that there is a definite relationship between these three properties. Magnetising Force (H), Flux Density (B), and Permeability (μ).

B is equal to μ multiplied by H ($B=\mu H$), and μ is equal to B divided by H $\left(\mu=\frac{B}{H}\right)$.

Now we have been considering, purely as an illustration, a coil of wire wound round a piece of iron with a current flowing through the coil.

It will be obvious that since the iron was in the form of a rod that the lines of force passing from one end to the other would have to travel through air and that therefore accurate measurements of its magnetic properties could hardly be taken in this manner.

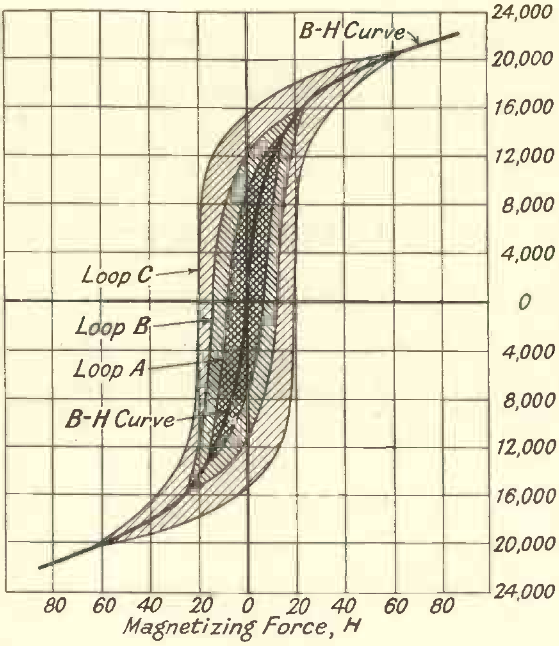


Fig. 2.—A Group or Family of Hysteresis Loops.
Showing B.H. or "tip-point curve."

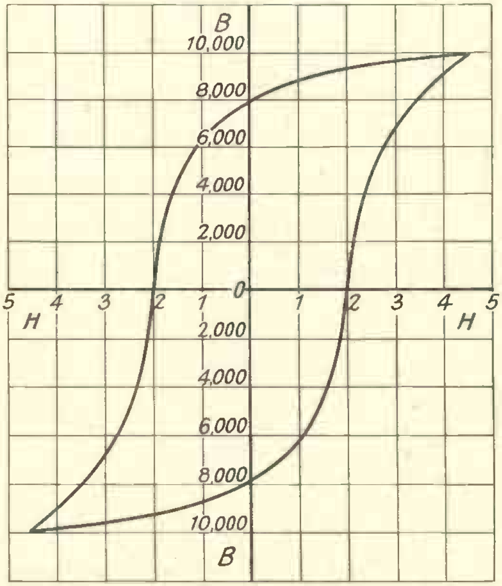


Fig. 3.—Hysteresis Loop of 22 Gauge Soft Iron Wire.

This was used extensively for cones of inter-valve transformers in 1922.

Demagnetising the Material before Test

A closed iron circuit is usually employed in taking such measurements and may take the form of a ring, a square or a rectangle. It is customary to demagnetise the material under test prior to the test. This is usually done by passing an alternating current through a coil round it and slowly reducing the value of the current to zero.

A Flux Meter

An instrument known as a Flux Meter is used to measure the flux density. A well-known type is the Grassot Flux Meter, which is really a form of galvanometer having a very lightly damped pointer which has been calibrated in flux lines under certain conditions. The pointer is so free to move that it takes many seconds, sometimes minutes, to return to its zero if displaced.

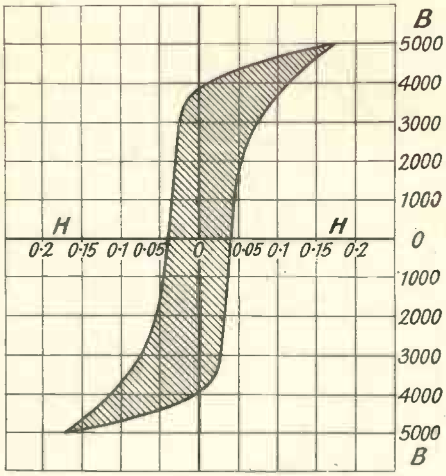


Fig. 4A.—Representative Hysteresis Loop for Permalloy "C."

(By courtesy of Magnetic and Electrical Alloys Ltd.)

RESIDUAL MAGNETISM AND HYSTERESIS

Now, assuming that we have a closed iron circuit of the type described above, together with suitable means for magnetising the iron and for observing the effect produced by such magnetisation, we can plot a graph showing the relationship between the magnetising force and the flux density, and if we carry the metal through a complete cycle of magnetisation and plot our graph we will have a figure described similar to a sort of S (Fig. 1). This figure is caused by residual magnetism and is usually called a Hysteresis Loop.

Hysteresis Loop

In Fig. 2 we have a group or family of such loops taken for several cycles of magnetisation. If we consider the curve in Fig. 1 we can by tracing out the curve observe how the magnetism B commences "lagging" behind after the magnetising force H, for that particular curve has reached its maximum in either a positive or negative direction. The cycle starts at O and the magnetism rises to X, and as the magnetising force decreases again to O it will be observed that B is now only at P or has lagged behind considerably. The lagging of B behind H is called "Hysteresis." Referring again to our "loop," the area enclosed by the loop will give the loss of energy due to hysteresis, and further where the curve cuts the zero line P the amount OP is the "Remanence," whilst OQ is the coercive force for the given maximum of B represented by that particular curve.

The BH Curve

Referring again to our family of curves, Fig. 2, the line joining the tips of the curves together and passing through the zero is known as the BH curve, and it is from this curve that the values of permeability or μ are taken.

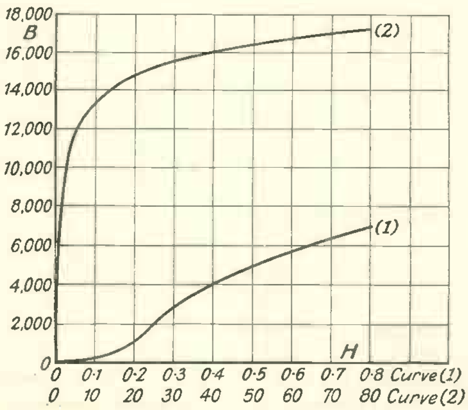


Fig. 4B.—Representative B.H. Curve for Permalloy "B."

(By courtesy of Magnetic and Electrical Alloys Ltd.)

Two things are immediately apparent. One being that the portions of the curves above and below the horizontal line are symmetrical, the other that the smaller the hysteresis loop the less loss will be experienced from this

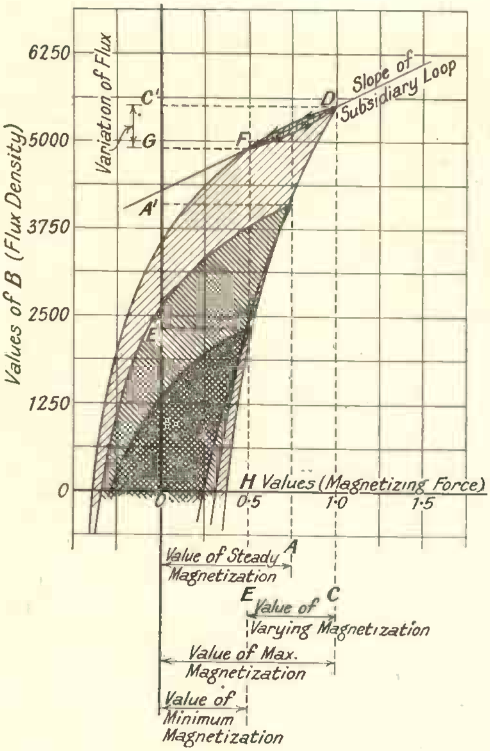


Fig. 5.—SUBSIDIARY HYSTERESIS LOOP.

cause. There are, however, certain cases where material having the larger loop may prove more useful, but such instances are few.

In Fig. 3 is shown a hysteresis loop for soft iron wire which was used extensively in 1922 for the cores of low frequency inter-valve transformers. Compare this with Fig. 4*a*, showing a hysteresis loop of Permalloy "C," a high permeability alloy.

In Fig. 4*b* we have a BH curve for Permalloy "B." A brief inspection of the curves in these three figures will show what considerable improvements have been made in the past few years in this direction.

So far we have merely considered the effect of carrying the metal through a complete cycle of magnetisation, starting with our magnetising force at zero, increasing it to maximum in one direction and then reducing it to zero, and repeating the performance in the opposite direction.

What happens if we impress first a certain magnetising force on the metal and vary it on either side of these limits, as is the case when an inductance such as a choke or primary of a transformer is connected in the anode circuit of a valve?

DIFFERENTIAL OR INCREMENTAL PERMEABILITY

What actually occurs in the instance cited above is that we have first a steady current flowing through the primary—which is the normal anode current of the valve—producing a magnetising force which we will designate as A in Fig. 5. Superimposed on this we have an alternating current which will one moment increase the magnetising force to a value C, and the next moment decrease it to E. In fact, the result will be similar to having a maximum magnetising force of value C, which is periodically decreased to E, and returns again to C—providing our A.C. does not fluctuate in value.

Further reference to Fig. 5 will show a family of hysteresis loops corresponding to the various magnetising forces E, A, C, etc. The tips of the loops, which are the maximum for that particular magnetisation, correspond to flux densities E′, A′, C′. Now the maximum magnetisation is at C and the minimum at E.

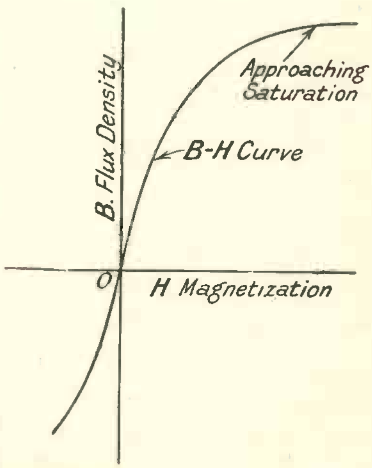


Fig. 6.—SATURATION CURVE.

As the magnetising force is increased a stage is reached when further increase produces extremely little or no change in the flux density. The iron is then said to be saturated with magnetism.

How the Correct Permeability Value is Obtained

How, then, shall we arrive at the correct permeability value for our varying magnetisation? Obviously we cannot obtain it by the old process of dividing B by H for either of these values. Let us endeavour to trace the variation of magnetism for a start. Commencing at our maximum magnetisation C, corresponding to a flux density C′, we will call the tip of the loop D. As our magnetising force decreases towards value E the magnetic flux will follow the curve of the hysteresis loop until we arrive at a point corresponding to E (see Fig. 5). We will call this point on the curve F equal to a flux density G. The magnetisation will again increase to C, and the magnetic force will rise from F to D, tracing a small loop as its path. This subsidiary loop is a result of the operation described, and the loss due to hysteresis under these conditions is only the amount equal to the area of this loop—a great deal smaller than would have been the case with the major loop. The line joining F and D gives what is known as the slope of this loop. The steeper this slope the greater will be the value of our differential permeability. It will be noticed that the tip of the subsidiary loop and the tip of the main one coincide as they obviously must do, the magnetisation at this point being the same for both.

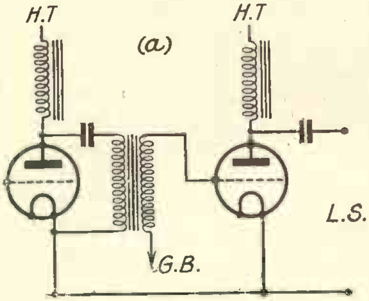


Fig. 7A.—Parallel Choke Feed with Choke Feed Output.

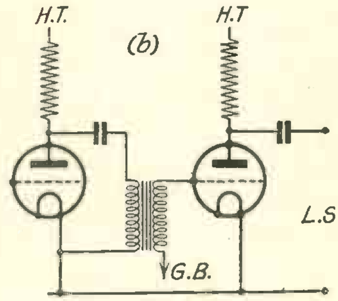


Fig. 7B.—Parallel Feed with Resistance Capacity Output.

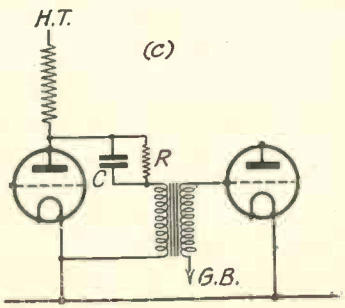


Fig. 7C.—Special Cone where Leak R across Condenser C allows a small Polarising Current to pass.

The Use of the Subsidiary Loop

If we now check the variation of flux density B for the change in magnetisation H we will obtain a value OC′ minus OG, which is equal to GC′ and OC minus OE equal to EC. It is usual to denote the small change in flux density B by the symbols ∂B or ΔB, and the small change in magnetising force H by the symbols ∂H or ΔH. From these values we obtain our value of differential permeability called $\partial\mu$ or $\Delta\mu$ by the simple process of dividing ∂B by ∂H, which is of course the same as dividing the value GC′ by the value EC.

This result is called the differential permeability, or, sometimes, the incremental permeability, and, in the case of inductances such as chokes, transformers, etc., used in valve circuits such as described, is the factor taken into account when calculating the inductance value in henries, etc.

Variation of Differential Permeability

It will easily be seen, from the foregoing remarks, that the value of the differential permeability will vary with (1) the polarising current, (2) the superimposed A.C. current; so, therefore, when using such components as chokes and inductances ascertain that the inductance value required has been checked for the required conditions under which it will operate.

With some metals, such as stalloy, the differential permeability is greater with a very little steady magnetisation than without. With others any steady magnetisation decreases the differential permeability value.

Saturation

Referring again to the paragraph describing the BH curve, and also to Fig. 6, it will be seen that as we increase the magnetising force and continue to do so we reach a stage where further increase of magnetisation produces extremely little or no change in the flux density. When this condition has been reached the iron is said to be saturated with magnetism.

The present-day high permeability alloys such as mumetal, radiometal and others approach saturation very easily, and various ways have been employed to obtain the maximum efficiency from them such as employing choke feed coupling and the parallel feed method. The circuits are shown in Fig. 7, *a*, *b*, and *c*. This arrangement diverts the steady current from the windings, and the differential permeability value is increased, enabling highly efficient units to be constructed in a small space such as the Benjamin " Transfeeda " and others. Under such conditions the full hysteresis loop is traversed, but with these new metals the area of the loop is so small that the loss of energy due to hysteresis is much less than would at first be imagined.

Compounds containing Metallic Dust

Magnets, such as are used for permanent magnet loud speakers, have been remarkably improved in efficiency for size compared with those of a few years ago. Nor are these the only directions to which attention has been given as lately compounds containing metallic dust have been introduced for tuning coils for radio purposes resulting, it is claimed, in coils of exceptionally high efficiency and small size which may, before very long, if the claims are true, be available for general use. Dynamo and motor design has benefited in recent years from advances in magnetic and other alloys, and there are many other directions in which these new improvements have been put to use which neither space nor time will permit the description of at present.

In conclusion, it may be of interest to the reader to note that one of the early forms of detector used for the reception of wireless signals was the Marconi Magnetic Detector, which made use of the fact that a piece of iron wire passing through a coil carrying H.F. currents literally had the hysteresis knocked out of it. The magnetic flux changing its position produced a sound in a pair of telephones. Needless to say, this form of detector whilst quite good for Morse was of little use for speech or music. What progress has been made since those days !

QUESTIONS AND ANSWERS

What is meant by " Permeability " ?

The ability of a substance to carry or conduct lines of magnetic force or flux. The permeability of air is taken as unity.

In what striking manner does the permeability of Iron or Steel differ from its Electrical Conductivity ?

The electrical conductivity remains the same whatever the value of the current flowing, but the magnetic permeability decreases as the flux density increases.

What is Residual Magnetism ?

When the current is switched off from an electro-magnet, the core remains more or less magnetised. This is called the residual magnetic effect.

The manufacture of permanent magnets depends on this effect.

Why are H.F. Coils made with Air Cores instead of Iron Cores.

Because the effect of residual magnetism at each reversal of current would damp out the H.F. currents.

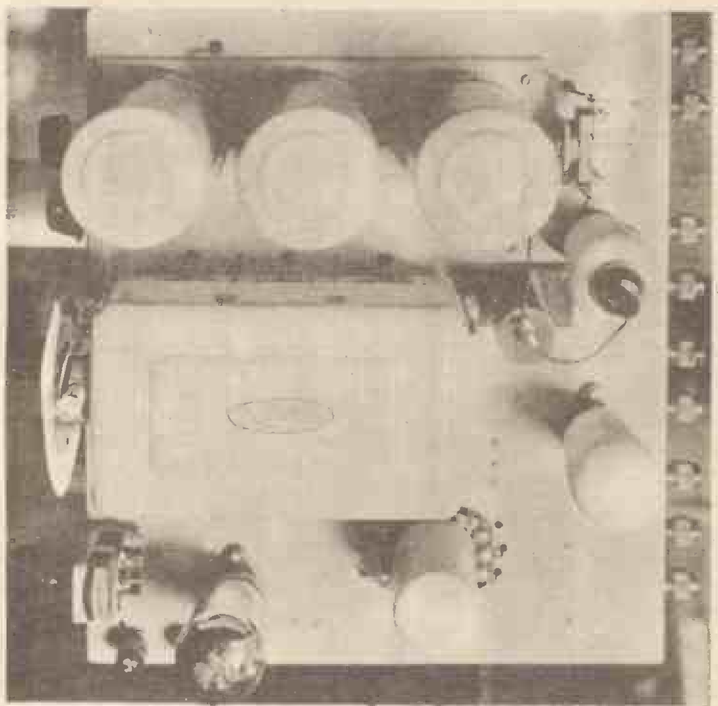
Can this be Overcome ?

A new material, consisting of metallic dust embedded in a binding compound, is said to exhibit no residual magnestism. This may solve the difficulty.

WITH PART 9.

NEWNES' "COMPLETE WIRELESS"

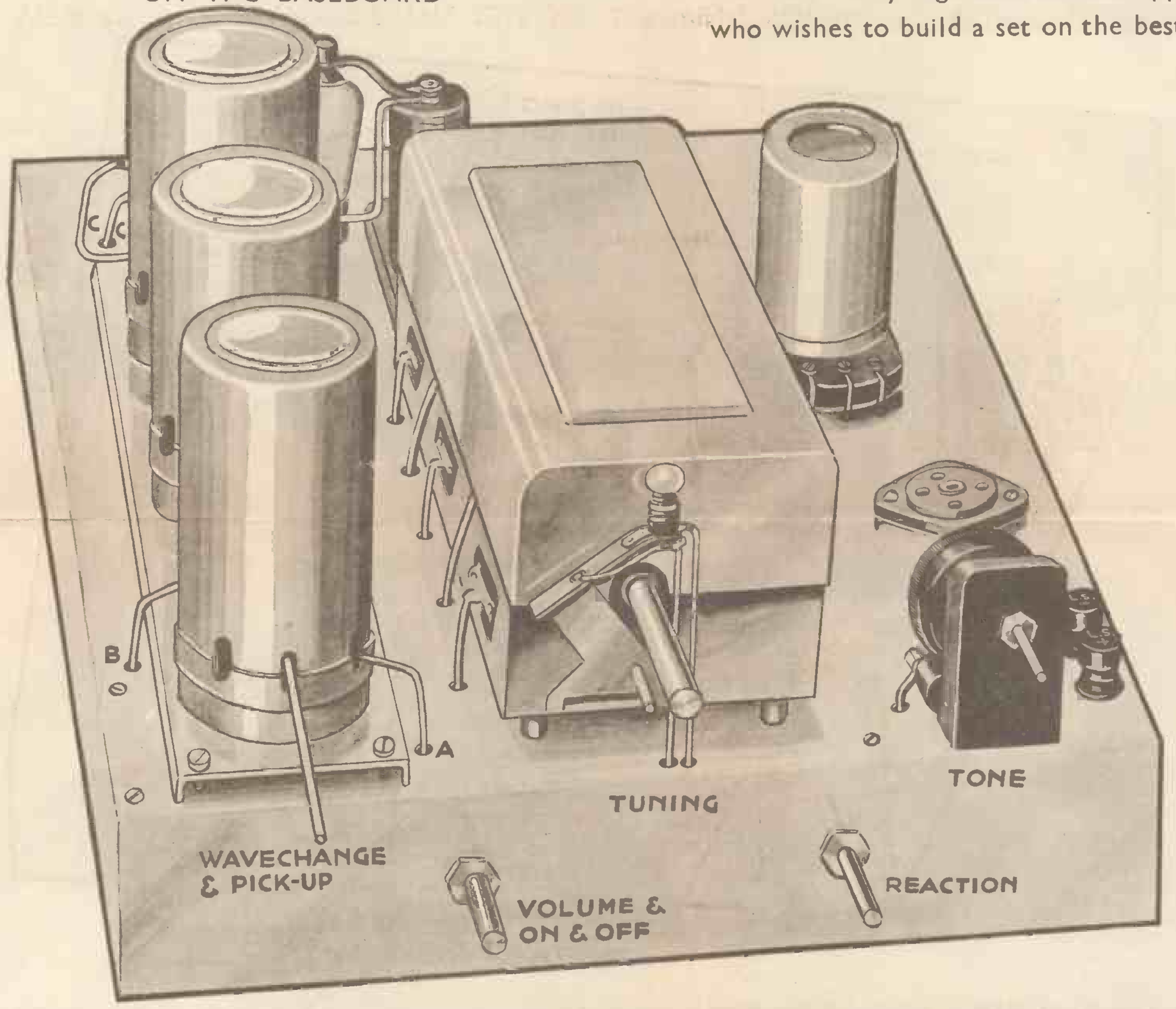
OPTIMUM THREE RECEIVER



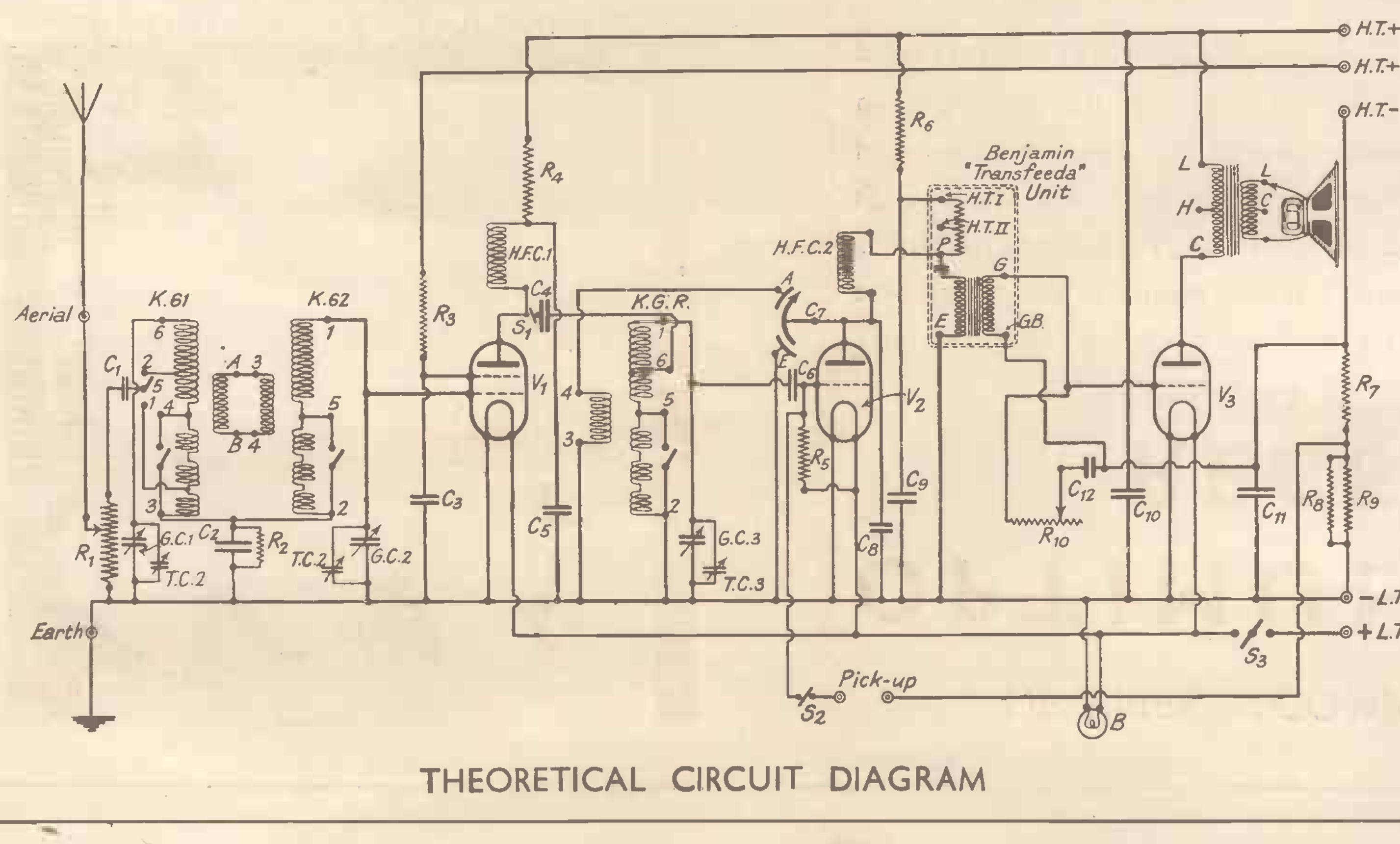
LAY-OUT OF THE COMPONENTS ON THE BASEBOARD

The receiver shown here represents best modern practice. It is assembled on a metal chassis which can, if desired, be purchased ready drilled with the ganged coils mounted in position. As can be seen from the diagrams, the circuit includes a tone control, and provision is made for gramophone pick-up. Over 60 stations have been logged on the test set, including 8 American stations, a fine performance for a three-valve assembly.

This really high-class set will appeal particularly to the constructor who wishes to build a set on the best professional lines.



VIEW OF THE FRONT OF THE CHASSIS, SHOWING WIRING TO COMPONENTS



THEORETICAL CIRCUIT DIAGRAM

LIST OF MATERIALS REQUIRED

1 3-gang condenser with right-hand trimmers, 349C, together with pillars for chassis support.
1 pilot-lamp attachment.
1 disc drive assembly.
1 5000-ohm volume control with Q.M.B. switch. Type 469. *British Radiophone Ltd.*
1 set ganged coils, K61, K62 and KGR, together with pick-up switch with pillar terminals for sub-chassis wiring.* *Colvern Ltd.*
1 Benjamin "Transfeeda," *Cat. No.* 8670. *Benjamin Electric Ltd.*
1 Pye differential condenser, *Cat. No.* 926. *Pye Radio Ltd.*
1 Lewcos H.F. choke, Type H.F.C.
6 coils 18 S.W.G. glazite. *London Electric Wire Co.*
2 10,000-ohm Sphagetti resistance ("Lewcos").
1 20,000-ohm Sphagetti resistance ("Lewcos").
1 1000-ohm Sphagetti resistance ("Lewcos").
1 300-ohm Sphagetti resistance ("Lewcos").
1 600-ohm Sphagetti resistance ("Lewcos"). *London Electric Wire Co.*
1 McMichael junior binocular choke. *L. McMichael Ltd.*
3 W. & B. skeleton valve-holders. *Whiteley Electric Radio Co.*
1 high-resistance potentiometer, 1 megohm. *Igranic Electric Co. Ltd.*
1 loud speaker +. 2 pick-ups.
1 loud speaker −. 1 L.T. +.
1 aerial. 1 L.T. −.
1 earth.
1 H.T. −, 1 H.T. +1, 1 H.T. + } all terminals, Type B.
1 screened grid valve connector.
2 packets washers for terminals, Type B. *Belling-Lee.*

2 2-mfd.	condensers, Type	50	*T.C.C.*
2 1-mfd.	,,	,, 50	
1 0·00025-mfd.	,,	,, S.	
2 0·0002-mfd.	,,	,, 34	
1 0·0001-mfd.	,,	,, S.P.	

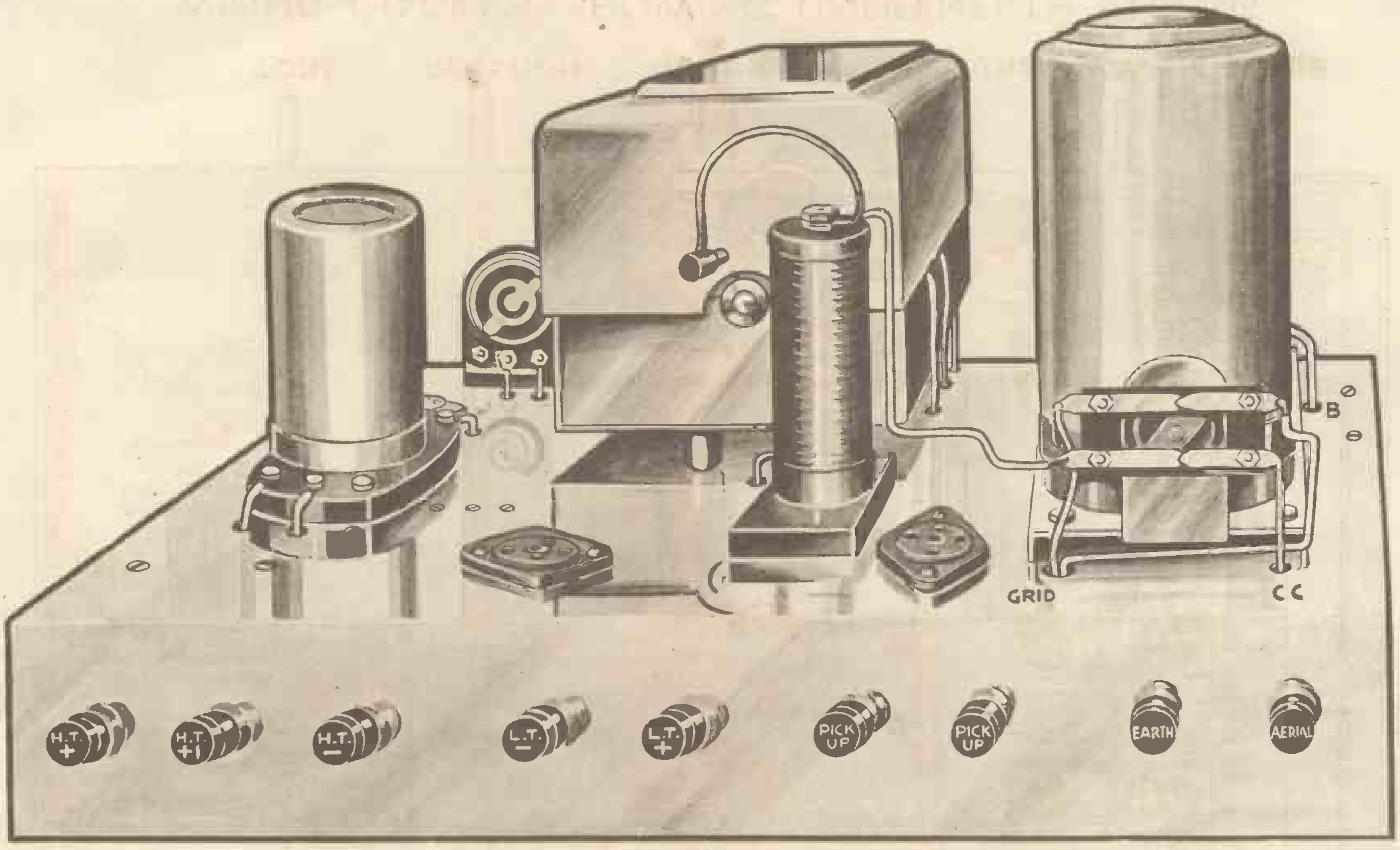
1 0·05-mfd. condenser with 1000-ohm shunt res., Type tubular.
1 0·001-mfd., Type S. *Telegraph Condenser Co.*
*1 Celestion M.C. loud-speaker with transformer P.P.M.9. *Celestion Ltd.*

1 S.G.215A. valve, metallised		*Mazda.*
1 H.2 ,, ,,		
1 P.220A. ,,		

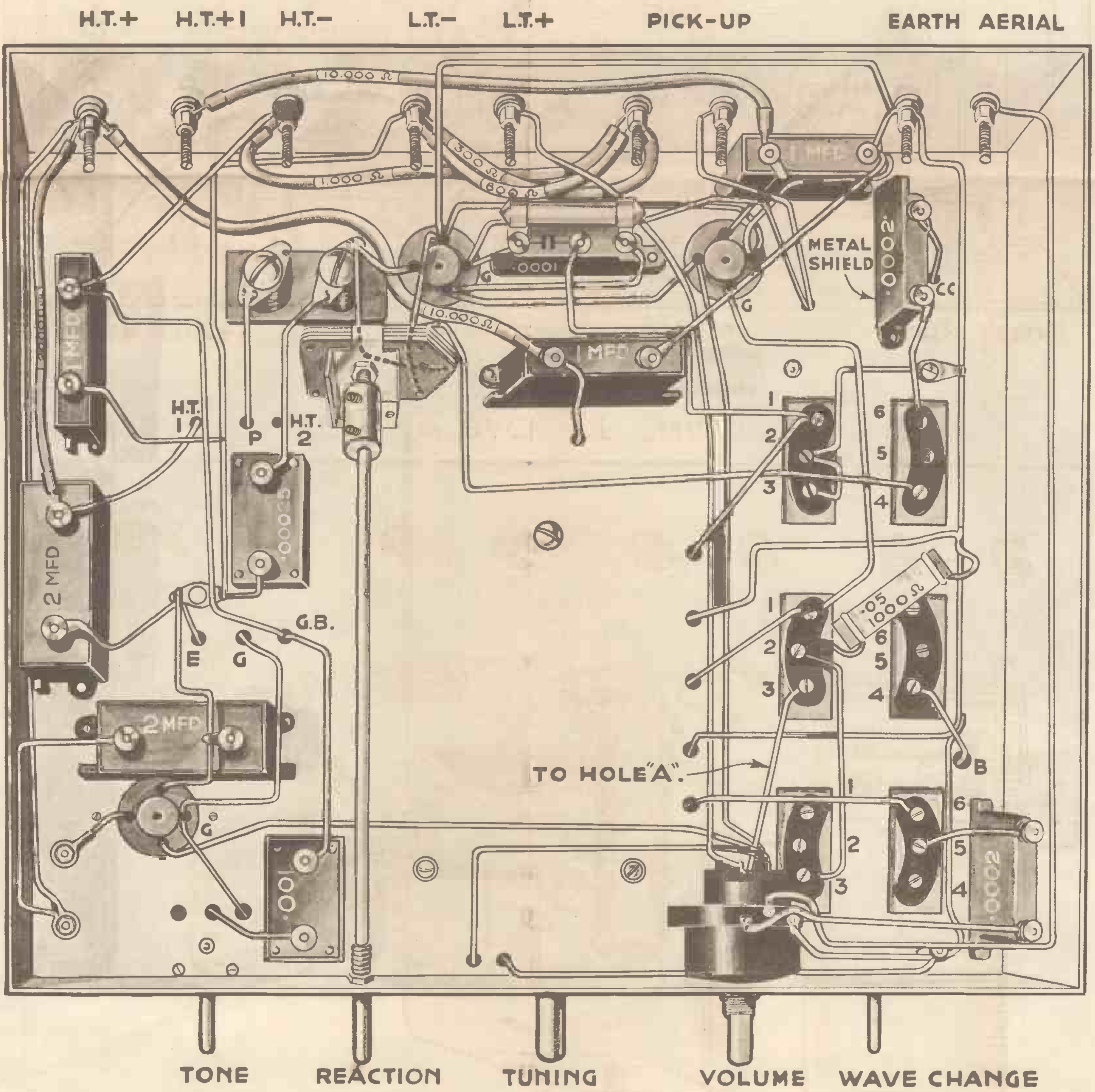
Ediswan Ltd.
1 grid leak, 2 megohms. *Loewe Radio.*

Quantity of bolts, nuts, and washers, as under :—
4 4B.A. ¾-inch cheese-head brass bolts.
4 4B.A. flex nuts.
4 4B.A. steel "Shakeproof" washers.
3 doz. 6B.A. ¾-inch roundhead brass bolts.
3 doz. 6B.A. flex nuts.
3 doz. 6B.A. steel "Shakeproof" washers.
16 "Shakeproof" terminals with wings. Clear $\frac{3}{16}$.
3 "Shakeproof" locking washers. Clear $\frac{7}{32}$. For use on ganged condenser bolts.
1 chassis, aluminium.*
1 bracket.
1 spindle, $\frac{3}{16} \times 10$ inches, brass.
1 collar for same with 2 grub-screws.
1 bush for same.
1 piece bakelite or hard ebonite, $3 \times 1\frac{1}{2} \times \frac{1}{4}$ inch.
H.T. Supply.—"Drydex" ideal batteries are the H3002 and H3003, but the 12 milliampere output size would suffice.
L.T. Accumulator.—"Exide," TZ3.

* The chassis ready drilled, with ganged coils mounted in position, can be purchased from Messrs. COLVERN LTD., Mawneys Road, Romford, Essex.



VIEW OF BACK OF CHASSIS



WIRING DIAGRAM, SHOWING UNDERNEATH CHASSIS

THE OPTIMUM THREE VALVE RECEIVER

By L. D. MACGREGOR

THE receiver described in the following pages is one of simple construction, ample selectivity and capable of delivering an output volume adequate for most domestic requirements.

In considering the design of the receiver it was decided to incorporate an arrangement so that the tone might be adjusted to suit individual requirements, and further that it might be used to minimise troublesome heterodyne whistles. Quality of performance was deemed to be of major importance.

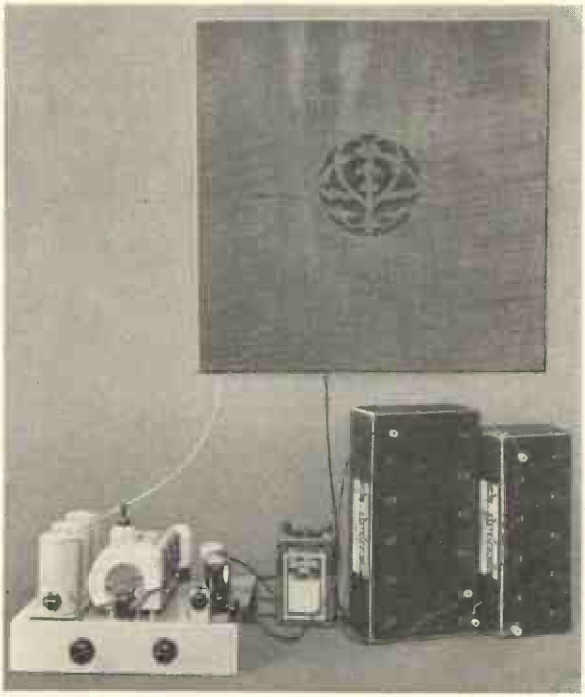


Fig. 1.—THE OPTIMUM THREE VALVE RECEIVER WITH BATTERIES AND LOUD SPEAKER CONNECTED READY FOR TEST.

Features of the Receiver

The Pre-H.F. volume control has incorporated with it the "on and off" switch, which comes into operation when the volume control is first moved from its zero setting.

Following this, we have a Colvern mixed band-pass filter, giving constant peak separation which feeds the H.F. stage. The coupling between H.F. and detector stages is that known as tuned grid coupling, and a ganged switch on the coil set changes wavebands and, in its mid position, switches the pick-up into circuit at the same time disconnecting the radio frequency supply to the detector from the H.F. stage. This is accomplished in such a manner that the usual "plop" accompanying such switching is conspicuous by its absence. The pick-up may, if so desired, be left connected to its respective terminals without interfering with the radio side, as this has been catered for in considering the switching arrangements.

The detector valve is coupled to the output stage by means of a Benjamin "Transfeeda." This little unit gives a very good performance and is remarkably compact.

Variation of tone is effected by means of a high-resistance potentiometer and a condenser, and may be used either on radio or pick-up.

Automatic bias is incorporated for both L.F. stage and pick-up, and suitable decoupling arrangements have been provided on all stages.

The receiver may be operated from either a 150-volt supply or a 120-volt

TEST RESULTS WITH THIS SET

Approximate dial settings on 100° dial.

LONG WAVEBAND

Kaunas	85°
Hilversum	80°
Radio Paris	70°
Zeesen	63°
Daventry National	57°
Eiffel Tower	48°
Warsaw	45°
Motala	40°
Moscow	35°
Kalundborg	24°
Oslo	17°
Kharkor	0°

MEDIUM WAVEBAND

Wilno-Poland	94°
Kaiserslauten	92°
Budapest No. 1	90°
Sundsvall	88°
Riga	86°
Vienna	84°
Brussels No. 1	82°
Florence	80°
Prague	77°
North Regional	74·5°
Langenberg	72·5°
Beromunster	69°
Paris P.T.T.	66°
Rome	64·5°
Stockholm	63°
Moscow	60°
Dublin	57°
Katowitz	56°
Sottens	54°
Midland Regional	52·5°
Frankfurt	50°
Toulouse	49°
Scottish Regional	46·5°
Hamburg	45°
Radio LL. Paris	44°
Muhlacker	42°
London Regional	41°
Strasbourg	38°
Brussels No. 2	36°
Milan	34°
Poste Parisien	33°
Breslau	32°
Genoa	28°
Bordeaux Layfayette	26°
North National	24·5°
Huizen	24°
Scottish National	22°
Heilsburg	18°
Turin	17°
London National	14°
Gleiwitz	11°
Trieste	9·5°
Belfast	8°
Nurnberg	7·5°
Cork	4·5°
Fécamp	4°

MEDIUM WAVEBAND (Long Distance Stations).

Miami—WIOD	5°
WMAC	8°
Philadelphia—WGAU	12°
Atlantic City—WPG	16·5°
WBG	18°
Westinghouse Station, New York WDVA / WGD	25°
New York—WABC	39°

supply without alteration of bias or decoupling devices.

Materials required for the Receiver

1 3-gang condenser with right-hand trimmers, 349C, together with pillars for chassis support.*
1 pilot-lamp attachment.
1 disc drive assembly.
1 50,000-ohm volume control with Q.M.B. switch. Type 469.
British Radiophone Ltd.

1 set ganged coils, K61, K62 and KGR, together with pick-up switch with pillar terminals for under chassis wiring.
Colvern Ltd.

1 Benjamin "Transfeeda," *Cat. No.* 8670.
Benjamin Electric Ltd.

1 Pye differential condenser. *Cat. No.* 926.
Pye Radio Ltd.

1 Lewcos H.F. choke, Type H.F.C.
6 coils 18 S.W.G. glazite.
London Electric Wire Co.

2 10,000-ohm Spaghetti resistances ("Lewcos").
1 20,000-ohm Spaghetti resistance ("Lewcos").
1 1,000-ohm Spaghetti resistance ("Lewcos").
1 300-ohm Spaghetti resistance ("Lewcos").
1 600-ohm Spaghetti resistance ("Lewcos").
London Electric Wire Co.

1 McMichael junior binocular choke.
L. McMichael Ltd.

3 W. & B. skeleton valve holders.
Whiteley Electric Radio Co.

1 high-resistance potentiometer, 1 megohm.
Igranic Electric Co. Ltd.

1 loud speaker +.
1 loud speaker −.
1 aerial.
1 earth.
2 pick-ups.
1 L.T. +.
1 L.T. −.
1 H.T. − } all terminals, Type B.
1 H.T. + 1 } all terminals, Type B.
1 H.T. + } all terminals, Type B.
1 screened grid valve connector.
2 packets washers for terminals, Type B.
Belling-Lee.

2 2-mfd. condensers, Type 50 } *T.C.C.*
2 1-mfd. " " }
1 0·00025-mfd. " " S. }
2 0·0002-mfd. " " 34 }
1 0·0001-mfd. " " S.P. }
1 0·05-mfd. condenser
1 1,000-ohm shunt res., Type Tubular.
1 0·001-mfd., Type S.
Telegraph Condenser Co.

*1 Celestion M.C. loud speaker with transformer P.P.M.9. *Celestion Ltd.*

1 S.G.215A. valve, metallised } *Mazda.*
1 H.2 " " }
1 P.220-A. " " }
Ediswan Ltd.

* A better, but more expensive model, the P.P.M.29, may be obtained if desired.

1 grid leak, 2 megohms.
Loewe Radio.

Quantity of bolts, nuts and washers, as under:—
4 4B.A. ¾-inch cheese-head brass bolts.
4 4B.A. flex nuts.
4 4B.A. steel "Shakeproof" washers.
3 doz. 6B.A. ¾-inch roundhead brass bolts.
3 doz. 6B.A. flex nuts.
3 doz. 6B.A. steel "Shakeproof" washers.
16 "Shakeproof" terminals with wings. Clear $\frac{3}{16}$.
3 "Shakeproof" locking washers. Clear $\frac{7}{32}$. For use on ganged condenser bolts.
1 chassis, aluminium or iron.
1 bracket.
1 spindle, $\frac{3}{16} \times 10$ inches, brass.
1 collar for same with 2 grub screws.
1 bush for same.
1 piece bakelite or hard ebonite, $3 \times 1\frac{1}{2} \times \frac{1}{4}$ inch.
H.T. supply.—"Drydex" ideal batteries are the H3002 and H3003, but the 12 milliampere output size would suffice.
L.T. Accumulator.—Exide. TZ3.

The chassis ready drilled with ganged coils mounted in position can be purchased from Messrs. Colvern Ltd., Mawneys Road, Romford, Essex.

CONSTRUCTING THE RECEIVER

The layout of the chassis for drilling purposes is as shown. Inspection of this will show the majority of drilling positions and sizes of drills required. There are one or two positions, marked *, where it is advisable to check the material at hand with the diagram, as in these cases variations are most likely to occur.

Having drilled all the requisite holes, care should be taken to remove burrs from the edges by means of a countersink bit, a large drill or a metal scraper. Appropriate slots should be filed in the holes, into which the Belling-Lee terminals fit.

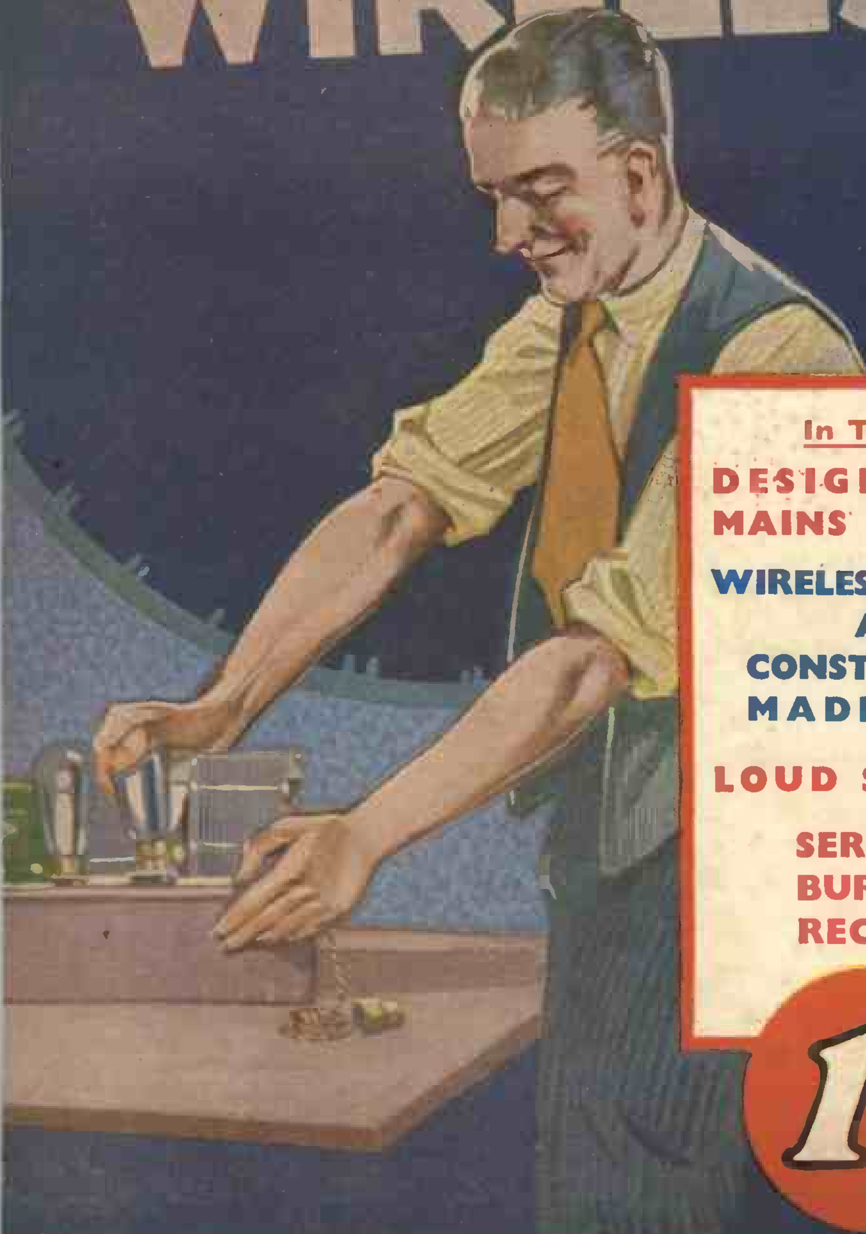
The next procedure is to ensure that all the components will fit in their respective places.

When this has been done the chassis may be given a coat or two of cellulose paint and left to dry. A suitable material

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS



In This Part

DESIGN OF A.C. MAINS RECEIVERS

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

LOUD SPEAKERS

SERVICING BURGOYNE RECEIVERS

1/-

Part 10

IN ABOUT 24 WEEKLY PARTS

GRIP

New "BOWSPRING" Wander plug

1½D.

Strong spring and wide self-adjustment. Side entry with Belling-Lee patent grip for flex. 12 Indications and 6 plain colours.

The "BOWSPRING" gives strong pressure over a far wider range of diameters than any plug we have so far tested.

BELLING-LEE

Write for list of radio connections.

Advert. of Belling & Lee Ltd., Cambridge Arterial Road, Enfield, Mdx.

You've the best for your set if you've

Exide AND Drydex BATTERIES

There is a type for every set

COLVERN COILS FOR EVERY MODERN RADIO RECEIVER

In receivers of outstanding design, Colvern Coils are incorporated.

That's why the following coils are specified for the

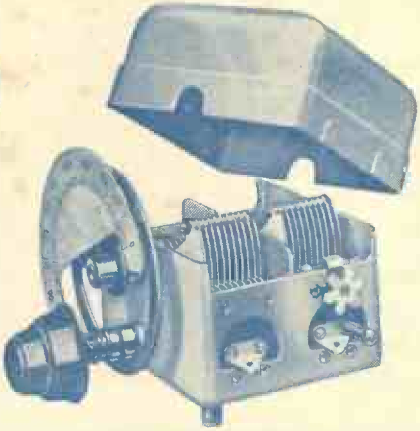
"OPTIMUM 3"
1 K61, K62, K.G.R. at 30/- per set.

1 Aluminium Chassis, ready drilled to take all components - 10/6 each.

Send for Colvern Booklet, RL10.

COLVERN LIMITED
ROMFORD · · · ESSEX

UNITUNE



Gives extremely fine tuning, the trimmer of front section being operated independently from the panel by a knob concentric with the main tuning knob.

Rigid one-piece chassis, very robust construction. Trimmer to each stage.

Matched to within ½ mmfd. plus ½ per cent.

Complete with disc drive and bakelite escutcheon plate.
Capacity ·0005. 2 gang, 18/6; 3 gang 27/-.

PRECISION INSTRUMENTS

Advertisement of Jackson Bros., 72 St. Thomas' St., London, S.E.1. Telephone: Hop. 1929.

for this purpose is light grey "Brushing Belco."

The Brackets

The brackets which support the reaction condenser and tone-control potentiometer may now be constructed, together with the coupling condenser shield.

Figs. 4 and 6 show the dimensions and details of these brackets. In these sketches the bracket for the reaction condenser is shown as being constructed from sheet aluminium, while the other one has been constructed from sheet Bakelite. Providing insulating bushes are available for the potentiometer, there is no reason why the bracket for it may not also be constructed from sheet aluminium.

The brackets having been constructed, they can be given a coating of cellulose paint and left to dry while the chassis is being assembled.

The screen for the coupling condenser, Fig. 10, may now be constructed.

A Few Precautions prior to Assembly

It is advisable carefully to check over all components for loose or tight terminals, etc., before assembly, as this will obviate any trouble which may occur later.

Attention should be paid to the ganged condenser and, prior to removing its cover, the spindle should be rotated clockwise to its fullest extent.

How Condensers go out of Gang

The removal of the cover whilst the vanes are in any other position than full mesh is likely to bend the split end vanes slightly—unless extreme care is exercised, combined with good luck—and this will throw the condenser out of ganging. Particular attention should be paid to this.

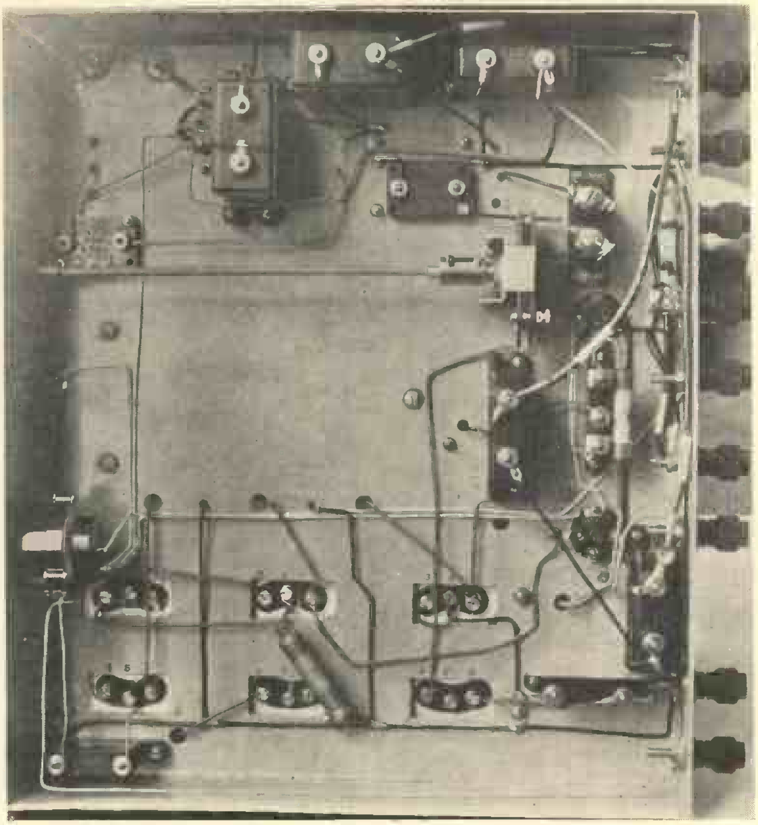


Fig. 2.—A View of the Underneath of the Chassis.

See that the recessed driving shaft is a good fit on its spindle, and if it shows any signs of tightness, drill it out. This is preferable to continual rubbing down of the spindle to make it fit. The spindle should be greased before assembly, and for the reasons stated above it is advisable to lock the disc drive when the condenser is set at maximum. Fit pilot-lamp attachment prior to assembly.

Pick-up Switch

Attention should be paid to the pick-up switch at the rear of the coil set to ensure that the contacts make and break correctly according to the switch settings. Should this not occur, it is in all probability due to screws having worked loose during transit, and they should accordingly be tightened.

Washers and Terminals

The writer recommends the use of "Shakeproof" washers and terminals, particularly where components are bolted to metal chassis. These save an immense amount of time and trouble due to nuts, bolts and terminals working loose at a later date. Should supplies of these be unobtainable from your local dealer, they may be obtained direct by writing to William Clark (Spare Parts) Ltd., 5 Marshalsea Road, London, S.E.1, giving dealer's name and address, and

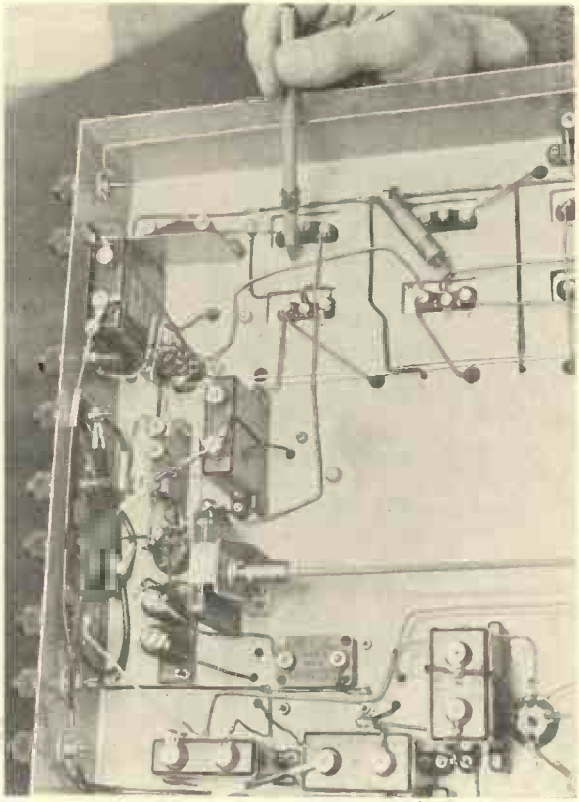


Fig. 3.—THIS SHOWS THE GRID WIRING TO THE DETECTOR VALVE.
Also the bracket for the differential reaction condensers.

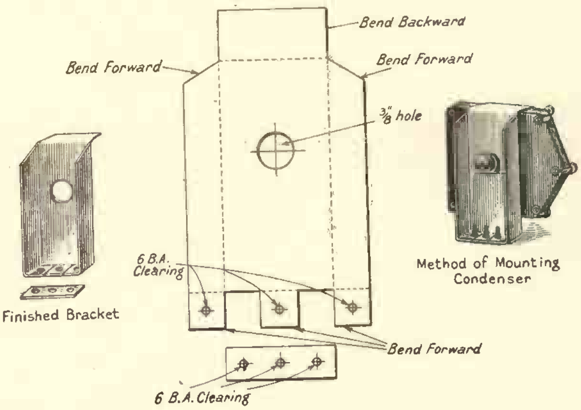


Fig. 4.—DETAILS OF THE BRACKET FOR THE REACTION CONDENSER.
The material to use is iron or aluminium.

mentioning this publication. The various resistances which are used for bias and decoupling purposes should then be tried out to see if their tags fit over the terminals to which they are to be secured. Should this prove not to be the case, the hole in the tag may be carefully opened out with a round file.

Mark, preferably with Indian ink, on the chassis, numbers and letters corresponding to the letters and numbers of the terminals on the case of the Benjamin Transfeeda. If this is done, and due care exercised in doing so, it will greatly facilitate operations later when it comes to wiring up.

The screen for the coupling condenser may be tried out for fit, and should the holes not quite coincide with the condenser fixing holes they may be enlarged by means of a file.

The "Shakeproof" terminals with wings, which fit on to the Belling-Lee terminals, should be checked for fit. If necessary, they can be enlarged slightly should they prove to be tight.

Examination of the Igranic Megostat will reveal three terminals—red, white and blue. Check the terminals for security, and bear in mind that the blue one should be connected to the grid of the output valve.

Assembling the Chassis

First examine the chassis and remove any superfluous paint which may have collected in the various holes. This will save messy fingers and exasperation later.

Commence the assembling in the following manner: First assemble the terminals in their respective positions at the rear of chassis, taking care to ensure that the lettering is facing the correct way and that appropriate washers are placed at the rear of the terminals. Only two terminals will have metal washers fitted—the "Earth" and "L.T. —" The remainder will be fitted with insulating washers and all should preferably have a double "Shakeproof" terminal, with wings, fitted after the washer, so that the wires may be soldered to these. The next item is the assembly of all components which go under the chassis. It will be noted that the fixing screws which hold the valve holders to the chassis are made use of to secure other components under the chassis and the valve holders will require to be fitted during this process.

This arrangement obviates unnecessary drilling and ensures the component being close to its respective valve holder.

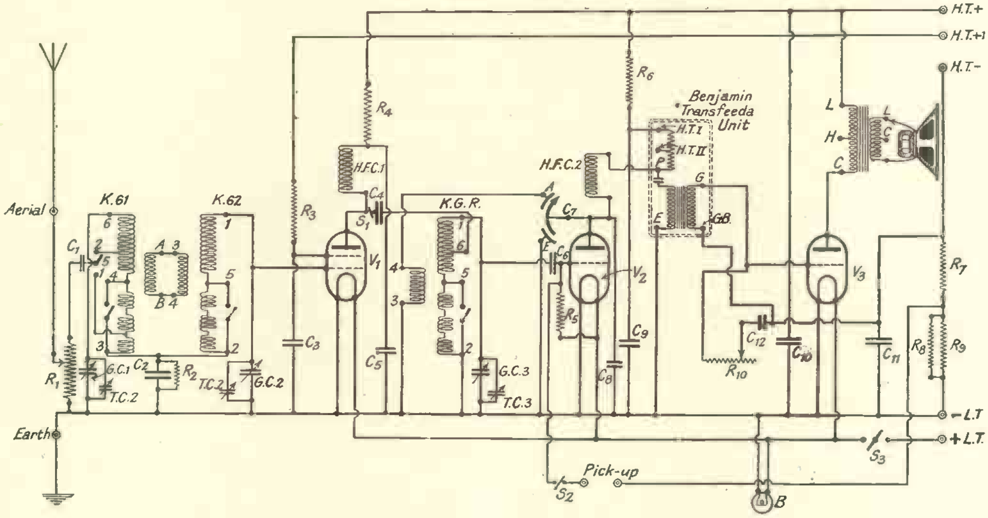


Fig. 5.—THEORETICAL CIRCUIT DIAGRAM.

C_1 and C_4, ·0002 mfd.; C_2, ·05 mfd.; C_3, C_5 and C_{11}, 1·0 mfd.; C_6, ·0001 mfd.; C_7, ·0003 Pye differential; C_8, ·00025; C_9 and C_{10}, 2 mfd.; C_{12}, ·001 mfd. G.C.₁, G.C.₂, G.C.₃, 1st, 2nd and 3rd gang condensers; T.C.₁, T.C.₂, T.C.₃, trimming condensers; H.F.C.₁ "Lewcos" Choke; H.F.C.₂, McMichael "Binocular"; R_1, 50,000 ohms; R_2 and R_7, 1,000 ohms; R_3 and R_4, 10,000 ohms; R_5, 2 megohms; R_6, 20,000 ohms; R_8, 300 ohms; R_9, 600 ohms; R_{10}, 1 megohm; S_1 and S_2, ganged switch at end of Colvern coil unit; S_3, ganged with R_1 . . . "on" and "off" switch; V_1, S.G. 215A (metallised); V_2, H2 (metallised); V_3, P220A (all Mazda); B, Bulgin 2 v. ·06 a. Competa bulb.

Assembling the Reaction Condenser

This is first assembled on its bracket and the bracket held to the chassis by its securing nuts and bolts, but these are not tightened up until the reaction condenser spindle is first lined up with the extension driving spindle. When this has been done the bolts can then be tightened up. Should there be any difficulty experienced in "lining up" this component, the hole in the front of the chassis—through which the bush for the extension spindle is placed—can be "drawn" or suitably enlarged or elongated by means of a file. Having completed the assembly of the parts under the chassis, next assemble those parts which go on top. It is advisable to commence by placing the ganged condenser in position first. To obviate undesirable capacity effects, this is held up from the panel by means of three pillars—and care should be exercised in the fitting of this to avoid straining it in any way. The coil set, together with the outer components, is then assembled and everything carefully checked over for position before commencing the wiring up of the receiver.

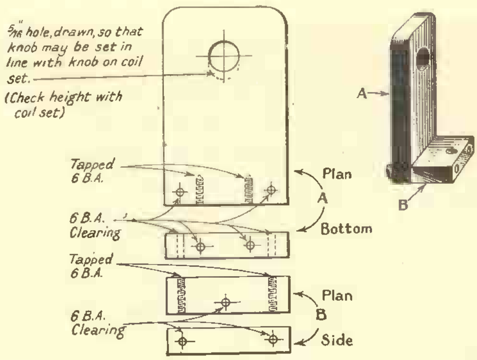


Fig. 6.—DETAILS OF BRACKET FOR TONE CONTROL POTENTIOMETER.

Material to use is $\frac{1}{4}$ inch Bakelite or hard ebonite.

A Precaution

When assembling the screen for the coupling condenser make certain that this will establish good electrical contact with the chassis. It is advisable to scrape clean the chassis just where the screen will fit and also to scrape the bottom of the foot of the screen.

WIRING THE RECEIVER

It is advisable to commence by first tinning all the tags which will eventually be soldered to, unless these happen to be already tinned.

Reference to the circuit diagram in Fig. 5 will assist during wiring. The method of wiring is shown in Fig. 2, and it is advisable to keep to this arrangement as far as possible, particularly in certain respects. Points where wiring variation is likely to cause unwanted effects will be dealt with as we proceed.

Where to commence Wiring

First wire up the — L.T. circuit with associated "earth returns." While doing this do not forget to include the wiring to the two springs which bear on the spindle of the ganged condenser. Removal of the cover will show the springs situated between 1st and 2nd and 2nd and 3rd gangs. With regard to the H.F. and detector valve holders, the earth return and — L.T. should be taken to a certain particular valve socket which corresponds to the valve pin to which the metallic coating on the bulb is connected. Fig. 12 illustrates this.

The next piece of wiring will be the L.T. + wiring. Starting from the L.T. + terminal this will go first to the switch on the volume control and from thence to the three valve holders and to the pilot lamp on the variable condenser bracket.

Having completed the wiring so far, test through to check the circuit and look for any abrasions of the covering which may have been made accidentally and which would cause a short circuit.

Wiring up the Three Coils

Next wire up the circuit of the three coils, paying particular attention to the terminal connections to ensure that no mistakes are made. Do not lay the wires flat along the chassis in all cases nor keep them so far from it that they act as miniature aerials. An average reasonable distance is from $\frac{1}{8}$ to $\frac{1}{4}$ inch. It is strongly recommended that the coil wiring and other H.F. wiring be carried out as far as possible in the same manner as in the receiver described, and much trouble will be avoided due to capacity effects and, what is even more important, the amplification from the H.F. stage will be kept at a high level.

Where Capacity Effects occur in the Wiring

In the case under consideration there are three main wires, together with their

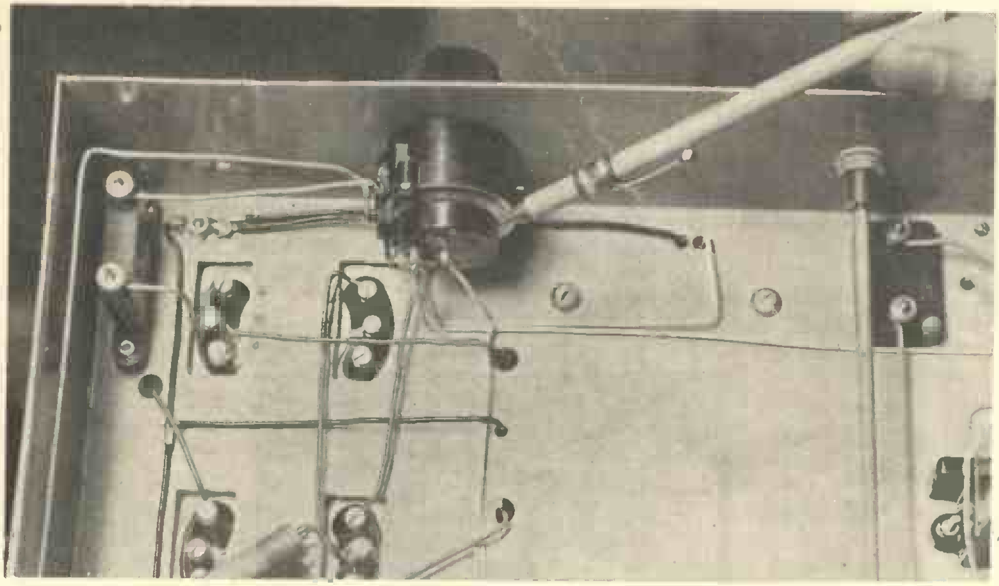


Fig. 7.—THIS SHOWS THE VOLUME CONTROL (50,000 OHMS) WHICH INCORPORATES THE ENCLOSED "ON" and "OFF" SWITCH.

associated wires, between which capacity effects are most likely to occur.

The detector grid wire and wires associated with its grid condenser and to the switch for pick-up.

The anode wires from the screen grid valve together with associated wires to the coupling condenser and tuned circuit.

The wire to the grid of the H.F. valve. This is the most susceptible of all of them and is kept within $\frac{1}{10}$ to $\frac{1}{16}$ inch off the chassis.

When wiring up the tone control connect the blue terminal of the potentiometer to grid.

Having completed the H.T. wiring together with the L.F. circuits, the bias and decoupling resistances may be fitted. The object of leaving these till last is that, should the necessity ever arise, they may be readily changed without disturbing the wiring. Such a contingency may arise when fitting an eliminator to the receiver.

Examine and Test First

Examine and test out the circuits carefully to ensure that all is in order, and having done this to your satisfaction connect up H.T. and L.T. batteries together with aerial, earth and loud speaker—leaving out the valves—and switch on. A pocket-lamp bulb connected across the filament sockets of each valve holder will indicate whether or no it is safe to insert the valves. During this process, operate all controls—one at a time. Should all prove to be satisfactory, the valves may be inserted after first switching off and the wave-change switch may then be set to cover the waveband on which the local station operates. The receiver may then be switched on for preliminary adjustments.

Adjusting the Receiver

It is advisable to start with a screening grid voltage of approximately 50 to 60 volts. This will be taken from terminal H.T. + 1, while terminal H.T. + will be connected to the maximum voltage of 150 volts.

Set the volume control to maximum. Unscrew the terminals on the ganged condenser and vary the tuning knob until signals are received from the local station. During this process the reaction should, of course, be set to zero. Should the local station give great volume this should be reduced to a reasonably low level by means of the volume control.

Starting with trimmer No. 1—that is, the trimmer nearest the dial end of the ganged condenser—vary the trimmers, one at a time, until the local station is tuned in on each of them. The receiver is now roughly ganged and in a state when further and more accurate ganging may be attempted.

Now adjust the screening grid voltage for best results. It will be found in general that a voltage of 72 to 81 is about the best adjustment.

Leaving the reaction at zero, switch over to long waves—or the other waveband—and check that the receiver is operating on both wavebands.

How to Gang the Receiver

Start with one waveband — preferably the medium—choose one or two stations giving weak but audible signals, whose dial settings are somewhere near the maximum. Carefully tune in the station and leave the tuning alone. Then, with the aid of a screwdriver, adjust the trimmers, commencing with No. 1, until the signals received are at their maximum strength.

Fig. 8.—METHOD OF SHOWING HAIRLINE ON TUNING SCALE.

If, during this process, the signals become very loud, leave that station and choose a nearby weaker one. It is exceedingly difficult to adjust the trimmers correctly on strong signals, as a slight trimmer variation will produce hardly any audible change.

Having adjusted the trimmers at the top of the scale, then readjust at the middle and bottom end of the scale and, finally, try the long waveband in the same manner. The main points to remember are the following :—

Set reaction at zero and volume at maximum.

Always choose a weak station to "gang" to for choice.

Never vary the tuning control whilst adjusting the trimmers.

Possible Variations

It may so happen that possible minor variations will occur in practice. For example, it may be that one or other of the trimmers requires more or less adjustment at one end of the scale than at the other. Adjustment in the nature of a compromise will then have to be effected, and should this occur it is advisable to "gang" accurately where the greatest selectivity is required. This will, of course, depend upon the local conditions and individual requirements.

A Practical Tip in Ganging

A very useful and easily constructed gadget, which greatly facilitates good ganging and can be made from a few pieces of scrap brass or tin with a length or two of brass rod or stiff wire, is that shown in Fig. 13. This is made so as to cover the moving vane of the trimmers and, if a flex has been attached to it, and earthed to chassis or – L.T., it can be brought up towards the trimmer vanes to increase capacity. This often saves the necessity of varying the trimmer screws and shows at a glance if more or less capacity is required and on which gang it is required. For best results use two of these gadgets. The wire handle may be bent to any desired position.

How to Diagnose Effects due to Condenser Variations

Reference to the article on Ganged Coil Circuits (page 291) will show the variation of wavelength to be expected due to coil variations; therefore it is not necessary to touch that point. There are, however, variations which occur in practice due to condenser gangs not quite matching at various settings. This may be due in some cases to the fact that the end split vanes have become bent during the removal of the cover.

The Remedy

This consists in bending the offending vane—away from the fixed vanes to decrease capacity or towards them to increase capacity. Use of the aforementioned gadget will determine which action should be taken.

A Caution

Check very carefully indeed before attempting to bend a vane, as when once bent it is not an easy matter to return it to the precise spot it previously occupied.

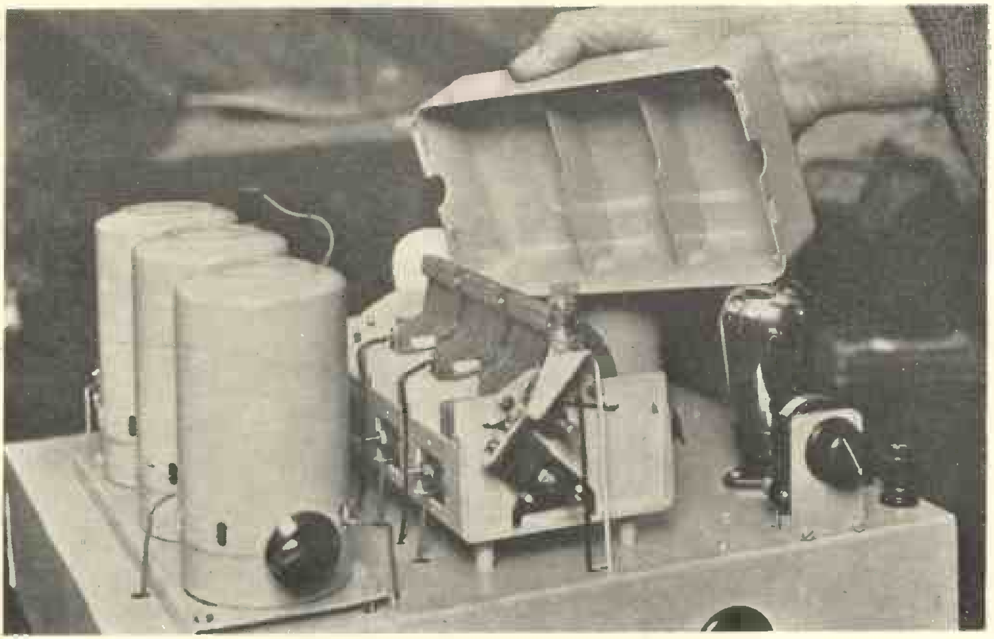


Fig. 9.—HOW *not* TO TAKE OFF THE COVER OF THE GANG CONDENSER.

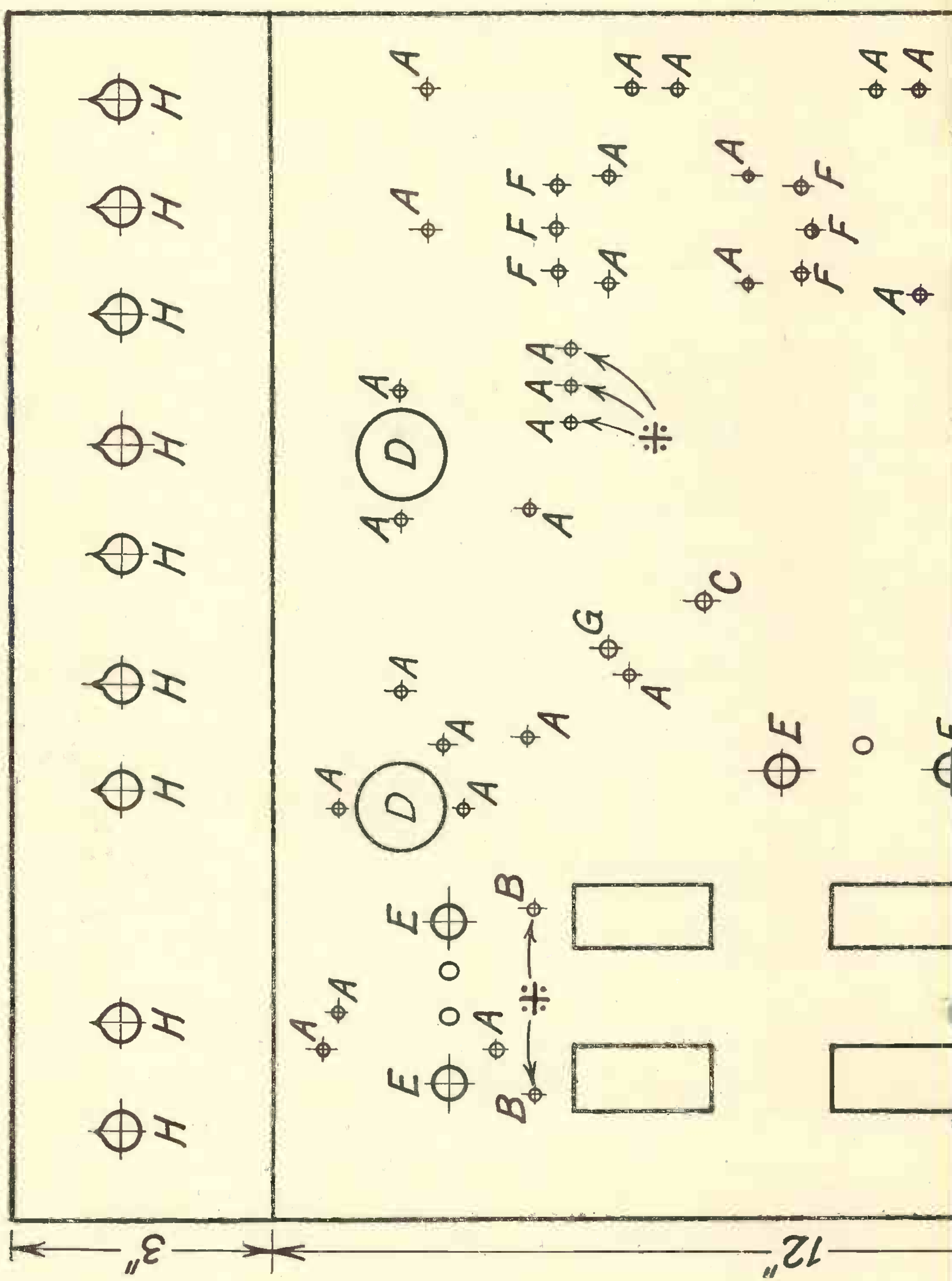
The cover should not be removed whilst the vanes are in any other position than full mesh, or else the split end vanes may be bent.

The usual signs of this are where a definite change of trimmer adjustment has to be made over an area covering only a limited number of degrees on the condenser scale, and after this area has been passed the trimmer has to be readjusted to its former position. In this instance the gadgets described in the previous paragraph are very useful as the additional capacity can be supplied by their aid without the necessity of varying the trimmer. This ensures the trimmer remaining at its previous setting. Do not bend with pliers, but rather with a stiff flat object, such as a broad knife blade. Do the bending a little at a time rather than too much at once.

PRACTICAL CONSIDERATIONS

Extra Selectivity

Should even greater selectivity than that obtainable with the receiver, as it has been described, be desired, this can be easily achieved by altering the value of C1. In place of a ·0002 mfd. a ·0001 mfd. could


H
A
D
E
B
F
G
C
3"
12"

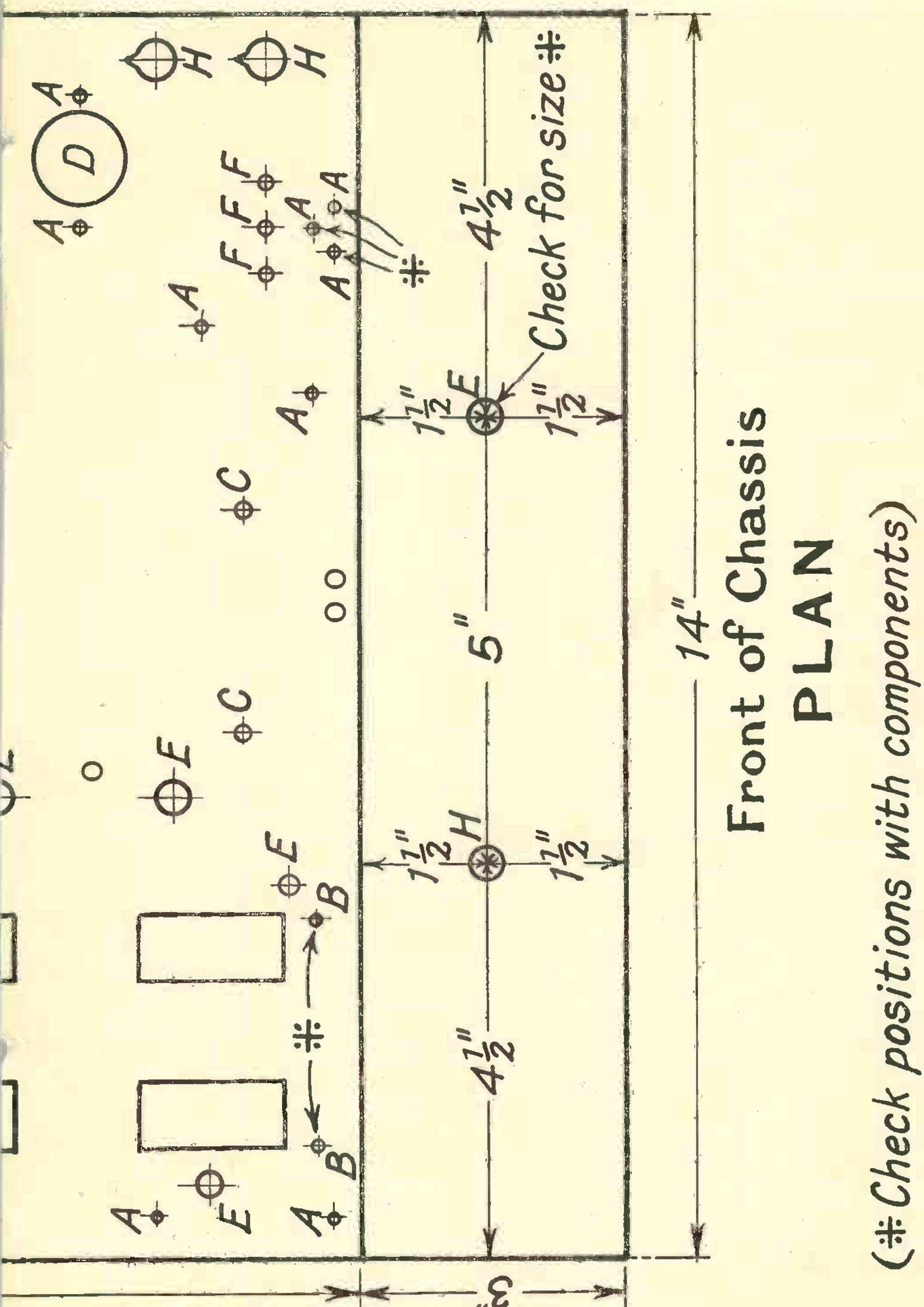


Fig. 9A.—Half Scale Layout of Chassis for Drilling, etc.

The drilling sizes are as follows:—A, 6 BA clearance; B, 4 BA clearance; C, $\frac{7}{32}$"; D, 1"; E, $\frac{5}{16}$"; F, $\frac{3}{16}$"; G, $\frac{1}{4}$"; H, $\frac{3}{8}$".

be employed, or if desired a preset condenser could be fitted and varied to suit individual requirements.

Very Modest H.T. and L.T. Consumption

For those who feel that 150-volt supply of H.T. batteries is rather beyond their means, it will be of interest to note that the receiver can, without further alteration, be used on 120-volt supply. The consumption on 150 volts is 10 milliamperes and on 120 volts 8 milliamperes. The L.T. consumption is very modest, being of the order of 0·5 ampere. There will naturally be a slight loss of volume on the lower voltage of 120, but this will not be serious.

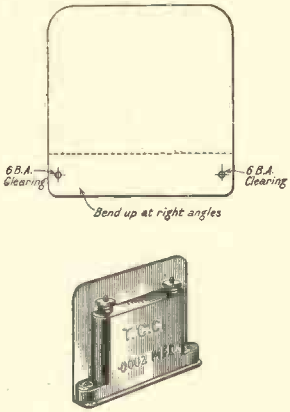


Fig. 10.—Details of the Shield for Coupling Condenser, also the Method of Assembling the Shield.

The material used is thin aluminium.

For Quality from Pick-up

When using a pick-up with this receiver and desirous of obtaining the best quality, it is recommended that a compensator of the " Novotone " type be used. It is not possible to arrange suitable compensation with the tone control in the receiver, as should this be attempted the amount of bass compensation to suit the average record would produce an overwhelming amount of bass on radio. The pick-up used should be of a suitable type for such purpose and the leaflet supplied with the " Novotone " describes suitable pick-ups.

Aerial

A suitable aerial for use with this receiver may be from 50 to 75 feet long. If in a locality where little interference is experienced from powerful transmitters, an aerial of 100 feet may be used if desired.

PERFORMANCE OF THE RECEIVER ON TEST

The receiver was tested out on a 100-foot aerial of approximately 25 feet average height with a view to ascertaining its performance under such conditions.

The input from the aerial was of such proportions that adequate volume could be obtained from the two London stations with the volume control at zero.

Results were most gratifying; over fifty stations were logged, and, given reasonably good conditions, over half this number could be received at good loud speaker strength. A table showing the stations received is on p. 439.

Selectivity

Considering the test conditions, selectivity was very good indeed. The receiver was perfectly stable on both medium and long wavebands, and, excluding the first 5 degrees of the medium waveband, where reaction varied the wavelength, smooth reaction could be obtained over the complete wave range of the receiver. The reason for the reaction not being useful over the aforementioned 5 degrees of the medium waveband is due to the fact that the use of reaction tends to increase the wavelength slightly on the coil on which reaction is used, and at these low settings it simply throws the tuned grid circuit out of ganging. Reaction can be usefully obtained by reganging, but is not worth the trouble in the majority of instances, and may affect the results on other stations.

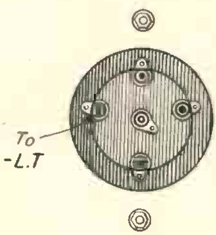


Fig. 11.—View of the Underside of Valve Holder.

Showing which leg should be connected to L.T. in case of H.F. and detector valves.

Sensitivity

The sensitivity of the receiver was very good indeed. With about 4 feet of wire attached to the aerial terminal and held in the hand, Radio Paris could be tuned in in the daytime at fair volume without reganging. In the evening many more stations could easily be received in this manner. During

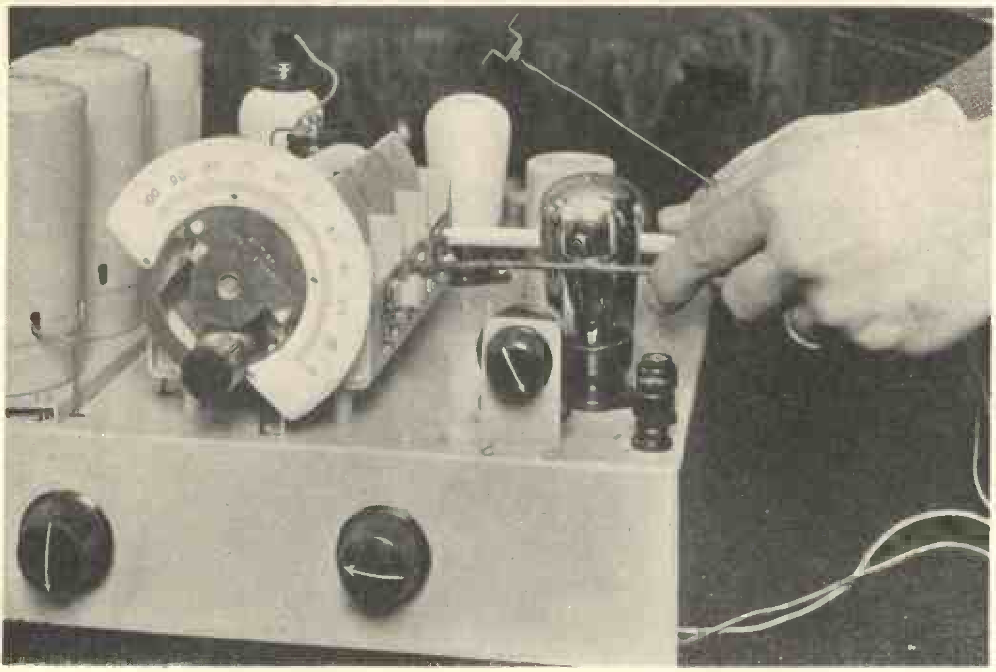


Fig. 12.—How to Trim the Gang Condenser.

An instrument constructed as shown below will be found useful.

the early hours several American stations could be received, reception varying considerably with atmospheric conditions. A list of those received during one night is given for reference.

The Pick-up

The pick-up may be connected to the receiver and left in this position without affecting the performance of the set. The wave-change switch in its mid position switches the pick-up into circuit.

The tone control incorporated was found to be particularly useful in eliminating undesirable heterodyne whistles, besides providing a ready means of adjusting the tone to one's own satisfaction.

Volume Control

The volume control was smooth in operation, and provided ample control under normal conditions. Whilst receiving far distant signals it was found advantageous to reduce the control slightly in order to obtain best results whilst using reaction. This operation has the result of reducing the effect of the aerial load on the first coil, and thereby slightly increasing the general efficiency.

It will be noticed that no bias is provided for the H.F. valve (S.G. 215 A). This particular valve can be used in this manner, as grid current does not start until the grid has reached a fair positive potential.

CALIBRATING

The Receiver

If the receiver be carefully ganged to dial settings corresponding to those given for various stations up to 20 degrees, the other settings

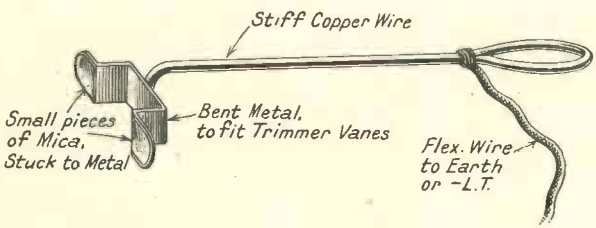


Fig. 13.—Details of instrument to facilitate ganging.

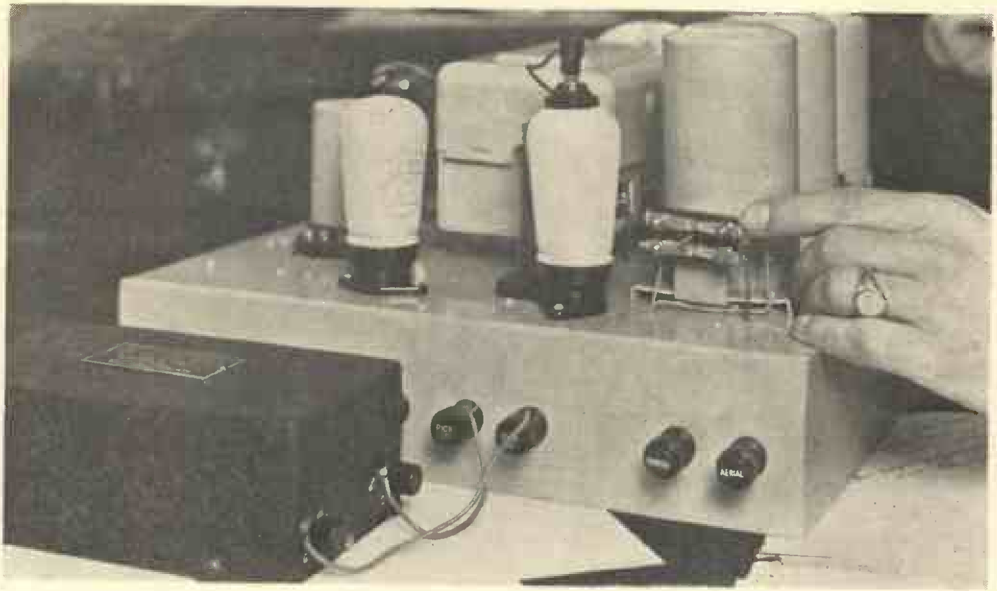


Fig. 14.—Details of the gramo and wave-change switch for cutting out H.F. side when using pick-up.

will be approximately the same as those given.

Settings may alter a degree or two, according to the amount of reaction used whilst tuning in.

Owing to the fact that many Continental transmitting stations do not stabilise their wavelengths, their settings will be found to vary from time to time, but the variation is, as a rule, slight.

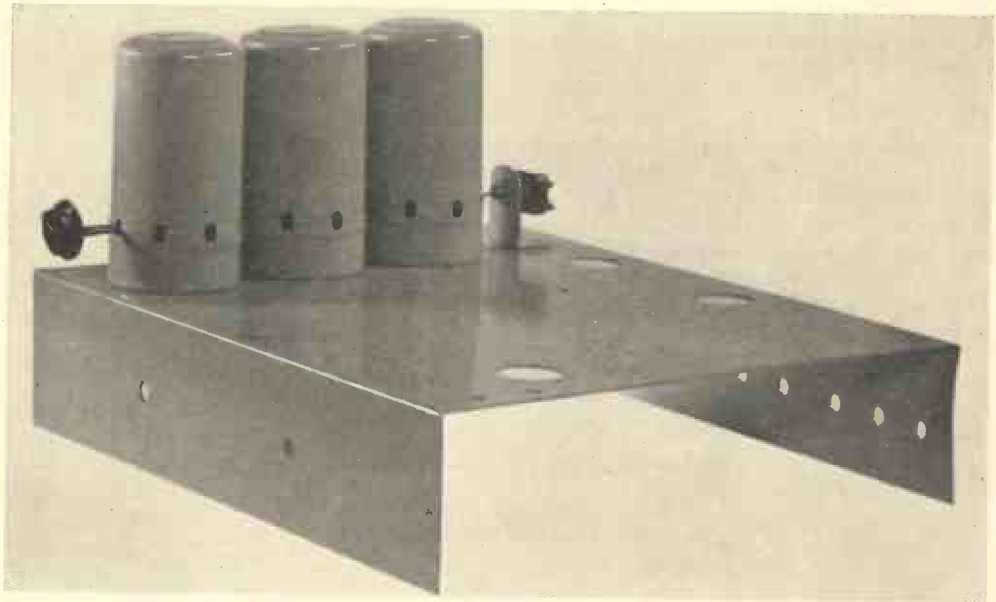


Fig. 15.—This shows the Chassis Complete with Coils Mounted in Position. This can be obtained ready drilled from Messrs. Colverns, Ltd., Mawneys Road, Romford, Essex.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION IX—CONDENSERS AND ALTERNATING CURRENTS

THIS is a very important part of our studies of the principles of wireless theory, as on it rests the understanding of the action of condensers in alternating current circuits.

For this reason it has been necessary to give a large series of diagrams illustrating the course of events in the charging and discharging of a condenser under the influence of an applied alternating E.M.F.

Readers are recommended to study again the previous article on condensers, and so refresh their memory as regards their action with direct currents.

A Very Simple Circuit

Let us consider a very simple circuit consisting of a source of an alternating E.M.F., say an alternator, across which is placed a condenser. If this condenser is to discharge, after it has been charged, it can do so only through the windings of the alternator itself. Although such a circuit is seldom used in practice, it will serve admirably for our present purpose.

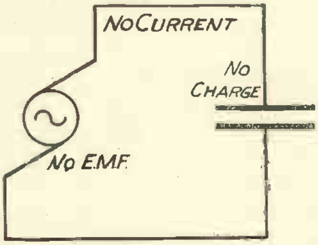


Fig. 1.—FIRST INSTANT OF OPERATIONS.

No E.M.F. is being applied by the alternator and no current is flowing in the circuit.

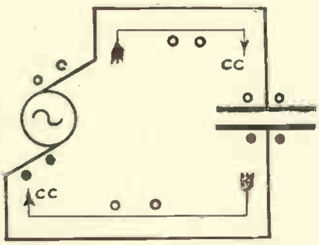


Fig. 2.—HERE TWO ELECTRONS ARE SHOWN AT ONE TERMINAL OF THE ALTERNATOR, AND THEREFORE TWO PROTONS ARE LEFT UNBALANCED AT THE OTHER TERMINAL. A CHARGING CURRENT BEGINS TO FLOW.

(In practice, of course, there are millions of electrons.)

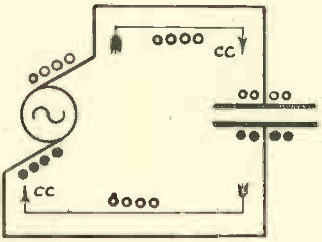


Fig. 3.—THE THIRD INSTANT.

The alternator E.M.F. has somewhat grown, and a stronger charging current is now flowing, while the charge on the condenser is accumulating.

The alternator is connected to an outside circuit *viâ* two brushes resting on slip rings, and what happens on the slip rings, as regards the instantaneous potential, happens across the brushes.

The E.M.F. of an alternator starts from nothing, *i.e.*, zero, gradually grows to a maximum (smoothly but very quickly), gradually diminishes to zero, reverses its direction, growing once more to a maximum and diminishing again to zero, only to reverse its direction once more and thus repeat the whole cycle of events.

Giving the Condenser its Initial Charge

Before we start to investigate the conditions prevailing in such a circuit, as described above, we have first of all to give the condenser its

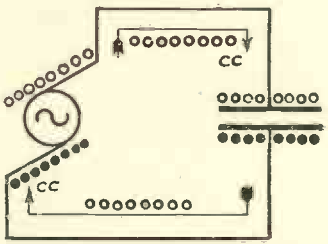


Fig. 4.—THE FOURTH INSTANT.

Here we see the moment when the alternator E.M.F. is at its maximum and the condenser is now fully charged.

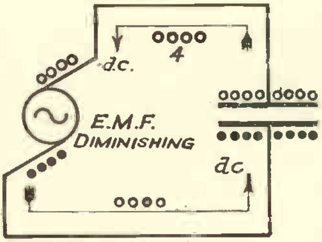


Fig. 5.—Here the Alternator E.M.F. begins to diminish.

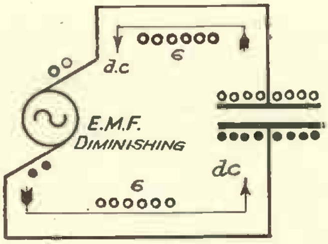


Fig. 6.—The Alternator E.M.F. still further decreasing.

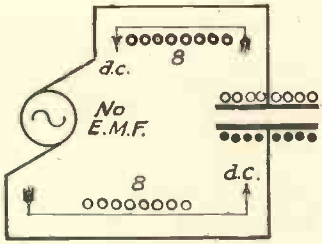


Fig. 7.—This shows the moment when the Alternator E.M.F. has disappeared for the time being and the Condenser is discharging at its Maximum Rate.

initial charge and then start investigating the cyclical variations taking place in the circuit.

For this reason we shall consider Figs. 1, 2, 3 and 4 as preliminary diagrams which have nothing to do with the periodical events which will take place after the conditions indicated in Fig. 4 have been reached. Once more electrons will be indicated in all diagrams as circles, while the unbalanced protons will be shown as black dots.

First Instant of Operations

In Fig. 1 we have the first instant of our operations when, at the moment there is no E.M.F. being applied by the alternator, no current is flowing in the circuit and therefore the condenser is as yet uncharged.

Electrons and Protons Unbalanced

In Fig. 2 we see, say for simplicity sake, two electrons appearing at one terminal of the alternator and therefore two protons being left unbalanced at the other terminal. The two electrons (in practice there are millions of them) will travel *viâ* the wire to the upper plate of the condenser, while at the same time two electrons will leave the lower plate of the condenser under the force of attraction of the two unbalanced protons on the lower brush or terminal of the alternator, this leaving on the lower plate two protons unbalanced. The net result is that a small current flows from the upper terminal of the alternator to the upper plate of the condenser, and at the same time a small current of the same magnitude will flow from the lower plate of the condenser to the lower terminal of the alternator.

In this manner, although a current does not travel *all round* the circuit, *i.e.*, it does not travel *through the condenser*, it will flow in the rest of the circuit and is really more of an electronic tide than a current in the ordinary sense of the word. This tidal electronic current is our *charging*

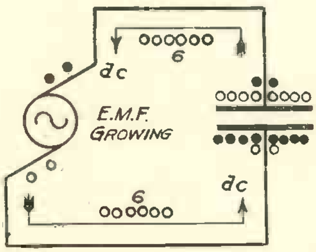


Fig. 8.—Here we see that the Alternator E.M.F. has reversed its direction, and begins charging the Condenser in the opposite direction.

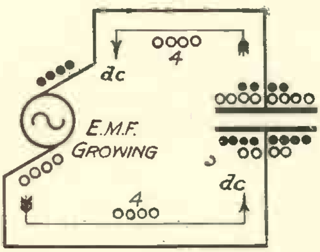


Fig. 9.—The original Charge on the Condenser is now rapidly diminishing and the Discharge Current is getting smaller and smaller.

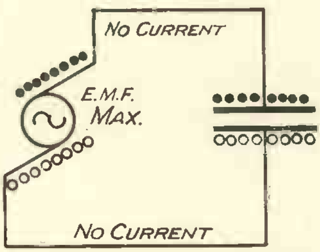


Fig. 10.—The Alternator E.M.F. is here at its maximum, the Condenser is once more fully charged, and no Discharge Current is flowing.

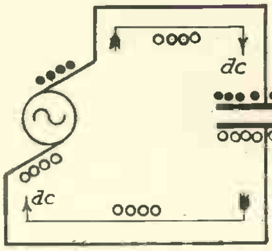


Fig. 11.—HERE WE SEE THE CONDENSER IS NOW DISCHARGING IN THE OPPOSITE DIRECTION AS THE ALTERNATOR E.M.F. IS DIMINISHING.

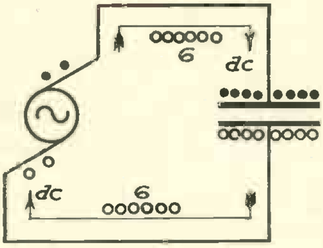


Fig. 12.—THE DISCHARGE CURRENT IS NOW INCREASING AS THE REVERSED ALTERNATOR E.M.F. IS DIMINISHING.

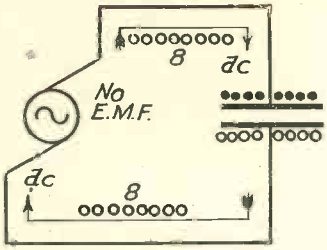


Fig. 13.—HERE WE SEE THE MAXIMUM DISCHARGE CURRENT IN THE REVERSE DIRECTION TO INSTANT 7.

current, a current which communicates to the plates of the condenser the same difference of potential as that prevailing across the terminals of the alternator.

The Condenser Fully Charged

From Fig. 3 we see that during the next instant (a small fraction of a second), the alternator E.M.F. has somewhat grown, and that a stronger charging current is now flowing. In Fig. 4 we find the moment when the alternator E.M.F. is at its maximum and the condenser is fully charged, after the final displacement of electrons has taken place.

How the Discharge Current is Formed

Now we are in a position to study the periodical events in our circuit. In Fig. 5 we find that the alternator E.M.F. is now diminishing, and that the E.M.F. produced across the condenser previously is still at its maximum. It is easily understood that we have now two E.M.F.'s in opposition. The alternator E.M.F. wants to send its surplus electrons from the upper brush to the upper plate of the condenser, and the condenser's upper plate wants to send its surplus electrons through the alternator to the lower plate of the condenser where they are lacking. The net result is that while the alternator is sending four electrons towards the upper plate of the condenser, the condenser is sending eight electrons in the opposite direction. Four electrons will stop another four electrons from going through on account of mutual repulsion, but the remaining four electrons will pass from the upper plate of the condenser through the alternator, and so to the lower plate of the condenser, thus constituting the discharge current of the condenser.

Maximum Discharge Current

From Fig. 6 it can be seen that as the E.M.F. of the alternator is further decreasing, the condenser will be able to send more electrons from its accumulated store, and the discharge current will further

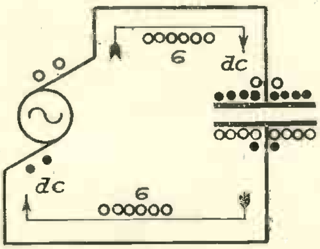


Fig. 14.—ONCE MORE THE ALTERNATOR E.M.F. IS REVERSED AND THE CONDENSER IS BEING CHARGED IN THE OPPOSITE DIRECTION.

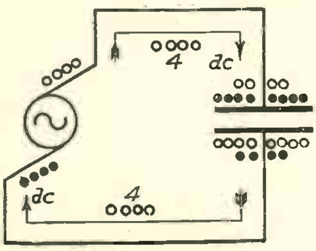


Fig. 15.—THE REVERSED E.M.F. IS GROWING AND THE DISCHARGE CURRENT IS DIMINISHING.

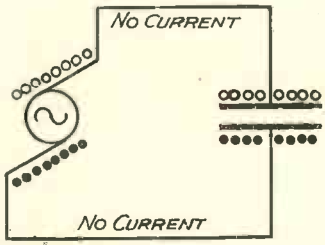


Fig. 16.—HERE WE SEE THAT THE CONDENSER IS ONCE MORE FULLY CHARGED IN THE OPPOSITE DIRECTION, AS DURING INSTANT 4.

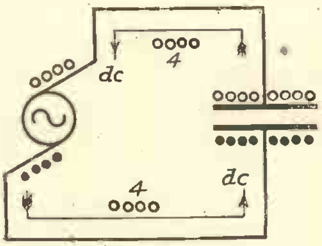


Fig. 17.—The Illustration given above shows a gradual increase to a Maximum Discharge Current.

increase. Please do not pay much attention to the simple figures I have chosen to illustrate the action of the condenser, but rather think of millions of electrons instead of the few I have indicated. Although we have seen from Figs. 5 and 6 that the condenser discharged some of its accumulated energy, its store is still plentiful, and it is just waiting for the alternator E.M.F. to disappear, for a moment, in order to send a maximum discharge current from one plate to the other through the windings of an, at the moment ineffective, alternator.

Energy Stored in a Condenser is Cumulative

It should not be forgotten that the energy stored in the condenser is a cumulative affair, and therefore this energy will last for some time, and will be always in opposition to the applied E.M.F. The condenser can be considered as supplying all the time a sort of back pressure. In Fig. 7 is shown the moment when the alternator E.M.F. has disappeared for the time being and the condenser is discharging at its maximum rate. In Fig. 8 the next instant is shown. Here we see that the alternator E.M.F. has reversed its direction, and the terminal, which before had unbalanced protons, now has surplus electrons, and *vice versâ.*

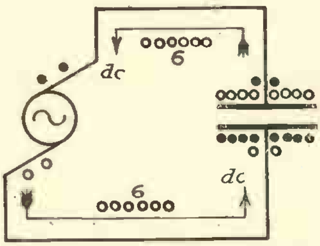


Fig. 20.—The Alternator and E.M.F. is reversed (as at Instant 8) and the Condenser is being charged in the opposite direction.

Charging in the Opposite Direction

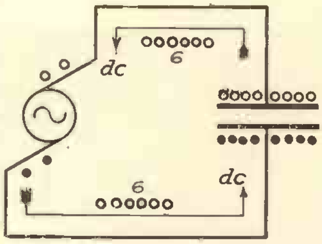


Fig. 18.—The Illustration given above shows a gradual increase to a Maximum Discharge Current.

The charge on the condenser is now rapidly diminishing and the discharge current is getting smaller and smaller, as can be seen from Figs. 8 and 9. What is happening now is that the condenser is being charged in the opposite direction. While this state of affairs prevails the condenser's resultant discharge current is always the difference between the condenser charging current and the condenser discharge current. In Fig. 10 we have the alternator E.M.F. at its maximum, no discharge current flowing at all, and the condenser charge is also at its maximum but in a reverse direction to that shown in Fig. 4.

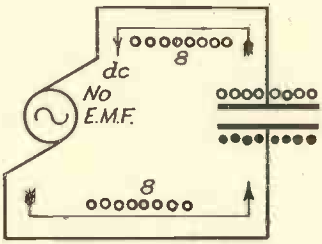


Fig. 19.—The Illustration given above shows a Maximum Discharge Current as at Instant 7.

From Fig. 11 you will see that the condenser is now discharging in the opposite direction as the alternator E.M.F. is diminishing. The maximum discharge current is shown in Fig. 13.

Gradual Increase to Maximum Discharge Current

From Fig. 16 we see once more the condenser is fully charged in the opposite

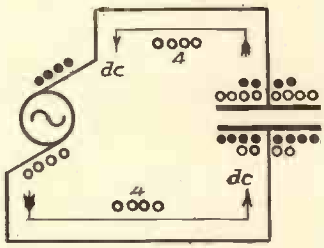


Fig. 21.—It will be seen that the Discharge Current is growing as at Instant 9.

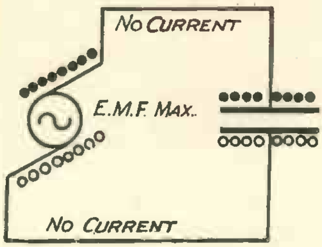


Fig. 22.—Here we see that the same state of affairs shown in Fig. 10 now prevails again.

direction to that shown in Fig. 10, and no current flowing. Figs. 17, 18 and 19 show a gradually increasing to a maximum discharge current. In Fig. 22 a state of affairs once more prevails as that shown in Fig. 10.

Direction of Flow of Discharge Current

In following the intensities and the directions of the discharge current, which is the resultant current flowing in the circuit, we see that in Fig. 5 the current is flowing from right to left in the upper portion of the circuit, and is flowing in the same direction in Figs. 6, 7, 8 and 9. In Fig. 10 no current is flowing, while in Figs. 11, 12, 13, 14 and 15 the current is flowing in the opposite direction. Fig. 16 shows another zero current, and in Figs. 17, 18, 19, 20 and 21 the current is flowing in the same direction as in Figs. 5, 6, 7, 8 and 9.

The Discharge Current is an Alternating Current

Thus it is clear that the condenser discharge current is following the same law as the E.M.F., and is subject to the same variations in intensity and direction as the E.M.F. Therefore the discharge current is an alternating current, always flowing only between the plates of the condenser *viâ* the alternator, but never *through the dielectric of the condenser.*

Combination of Charging and Discharging Currents

Thus the common statement that condensers *let through* alternating currents is sheer nonsense. The current flowing in the rest of the circuit is merely a combination of charging and discharging currents. Please study carefully Figs. 1 to 22, which are introduced in order to avoid the complications of curves and so-called vector diagrams. In Figs. 8 and 9, 14 and 15, and 20 and 21 I have shown over the plates of the condenser a double row of electrons and protons. This method is used to show how the charge on the condenser is becoming smaller and smaller as the arriving electrons neutralise the unbalanced protons and thus diminish the number of unbalanced protons and electrons on the two plates.

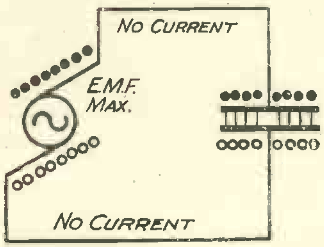


Fig. 23.—Here it can be seen that when the E.M.F. is at a Maximum and no Current is flowing in the Circuit, the Condenser Charge is also at its Maximum and therefore there is a Maximum Electric Field between Condenser Plates.

Leading Currents and Lagging Currents

Although the discharge current is of the same alternating character as the applied E.M.F. of the alternator, you will notice that they do not happen at the same time. When the E.M.F. is zero the current is at a maximum. Thus the current, being a discharge current, happens always before the E.M.F., and for this reason we say that condenser discharge current *leads* the E.M.F., and is a *leading current.* A current flowing through a coil, *i.e.*, an inductance, on the contrary lags behind the E.M.F., and is called a *lagging current.*

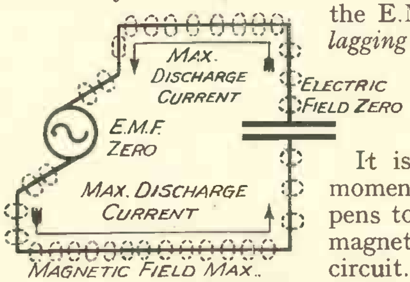


Fig. 24.—Applied E.M.F. Zero, Discharge Current is at its Maximum. Maximum Magnetic Field and no Electric Field.

The Electric and Magnetic Fields

It is interesting, at this moment, to see what happens to the electric and the magnetic fields around our circuit. From Fig. 23 it can be seen that when the E.M.F. is at a maximum and no current is flowing in the circuit, the condenser charge is also at its maximum, and therefore there is a maximum electric field between the plates of the condenser. In Fig. 24 the applied E.M.F. is zero, the current is at its maximum, and therefore there is a maximum magnetic field and no electric field.

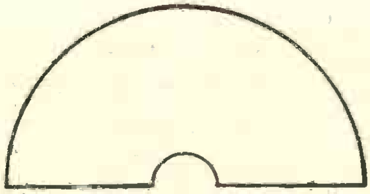


Fig. 25.—THE OLDEST TYPE OF CONDENSER VANE.

Thus, when the magnetic field is at its maximum the electric field is zero, and *vice versâ*. As the magnetic field grows the electric field diminishes, and as the electric field grows the magnetic field diminishes. Please remember this, as it will come into our discussion of the aerial and earth as part of the tuning circuit.

Fig. 26.—A STRAIGHT LINE FREQUENCY CONDENSER VANE.

Fixed and Variable Condensers

Now, let us go a step further. As we already know, there are two main types of condensers, fixed and variable. In the case of the fixed condensers the capacity remains always the same, as the plates are permanently fixed in respect to each other.

Capacity of a Variable Condenser

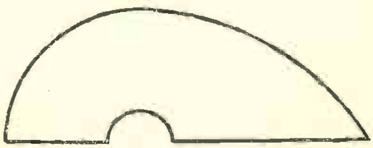


Fig. 27.—A STRAIGHT LINE WAVELENGTH CONDENSER VANE.

The capacity of a variable condenser is varied by moving one set of vanes in respect to the other set, the *overlap area* of the vanes determining the capacity in a given position of the two sets of vanes. We shall discuss later why such variable condensers are necessary for wireless work, but in the meantime let us consider the various types of such variable condensers. These types differ by the shape of the vanes in the case of condensers the capacity of which is being altered by moving one plate over the other.

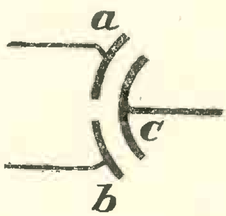


Fig. 28.—A DIFFERENTIAL CONDENSER.

Types of Condensers and their Effect on Capacity

The oldest type is that with semi-circular vanes (Fig. 25). As this type of condenser is liable to crowd the readings at one end of the scale, other types have been devised which give a better distribution of readings, *i.e.*, the variation of capacity is more evenly distributed over the scale. The modern types consist of the so-called *straight line frequency condenser*, the vane of which is shown in Fig. 26, and *straight line wavelength* condenser (Fig. 27). There is a third type, called the *logarithmic condenser*, the vane of which is similar to that of the straight line wavelength condenser, and is used chiefly for ganging purposes.

The relation between the variation in capacity for every degree of turning of the vane will be discussed in the mathematical portion of this work, and the corresponding tuning graphs will be shown.

Tubular Variable Condensers

Tubular variable condensers were used in the past for the purpose of neutralising the inter-electrode capacity of the valves. In this case one cylinder slides inside the other, and again as the overlap of the cylinders varies the capacity varies. The maximum capacity occurs when the cylinders are fully overlapping and the minimum capacity when there is no overlap. I said minimum capacity because with a variable condenser, even if there is no overlap between the condenser vanes, there is still some small capacity remaining. Thus, the designers, being unable to produce a condenser with a zero capacity, endeavour to make this minimum capacity as small as possible. Such tubular neutralising condensers are known as neutrodyne condensers.

The " Pix " series aerial condenser is of a similar type, having one cylinder sliding inside another.

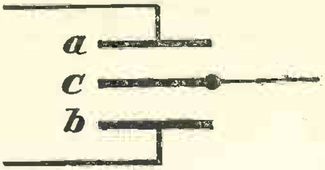


Fig. 29.—Showing how a Differential Condenser really represents Two Condensers in Series.

Differential Condensers

Then there is the so-called differential condenser, which is usually shown diagrammatically, as in Fig. 28. This condenser really represents two condensers in series, as can be seen from Fig. 29. From Fig. 28 it can be seen that when the rotating vane is being moved the ratio between the capacities of the two condensers is altered. Such an arrangement provides a larger range of adjustments.

The practical application of all such condensers will be found in other parts of this work.

Current cannot go through the Dielectric

It should be clear from this and the previous article on condensers that whatever the nature of the current it cannot go through the dielectric. In the case of a direct current, since the E.M.F. applied to the condenser remains constant and is always in the same direction, all it can do is to charge the condenser, and since now the applied and the condenser E.M.F.'s are equal and opposite, no discharge can take place.

If the applied E.M.F. is weakened for some reason or other, and becomes smaller than the condenser E.M.F., then a discharge will take place. This is what is happening in the case of an alternating E.M.F. ; it periodically weakens and enables the condenser to discharge.

We have now progressed far enough to be able to discuss in the next articles the nature, behaviour and propagation of wireless waves in order to step over naturally to the first part of the receiver, its aerial tuning circuit. Having made a thorough acquaintance with the latter, we shall discuss in detail the action of a thermionic valve and survey the modern valves so that the remaining parts of the receiver can be discussed without any difficulty.

QUESTIONS AND ANSWERS

What is meant by a Leading Current ?

In an alternating current circuit, the current and voltage are not usually in step. That is to say, the current and voltage do not attain their maximum values at the same instant. In some cases the voltage is at a maximum a fraction of a second before the current has reached a maximum, and in other cases a fraction of a second after. If the current attains maximum value before the E.M.F. reaches a maximum, it is said to be a leading current.

What is meant by a Lagging Current ?

A lagging current in an alternating current circuit is one that reaches a maximum value after the applied E.M.F. has attained maximum.

What is the Effect of placing a Condenser in an Alternating Current Circuit ?

A condenser produces a leading current in the circuit in which it is connected.

How could you provide a Lagging Current in such a Circuit ?

By inserting an inductance in the circuit.

Is it possible to have Current in an A.C. Circuit neither Lagging nor Leading ?

Yes. The current and voltage can be brought into step or " into phase " by suitably proportioning the capacity and inductance of the circuit.

THE DESIGN OF A.C. MAINS RECEIVERS

By H. E. J. BUTLER

THE purpose of this article is to deal with the principles involved in the design of the mains equipment of A.C.-driven receivers. The methods of obtaining the various smoothed high-tension and grid-bias voltages are fully described, and two example receivers are given to illustrate the methods of determining the values of the different components.

The Valves

With the exception of certain types of output valves, the valves used in A.C. receivers are of an entirely different type from those used in battery driven receivers. In a battery receiver the filaments of the valves are heated by a direct current supply in the form of an accumulator. In a mains receiver, on the other hand, the filaments, or cathodes, as they are more correctly termed, are heated by a tiny heater, which is supplied with "raw" A.C. It must be remembered that it is essential only to heat the cathodes or filaments, and not necessarily to pass a current through them. In a battery valve, therefore, the filament serves as heater and a cathode at the same time, while in an indirectly heated mains valve the heater and cathode are separate, and insulated from one another inside the valve.

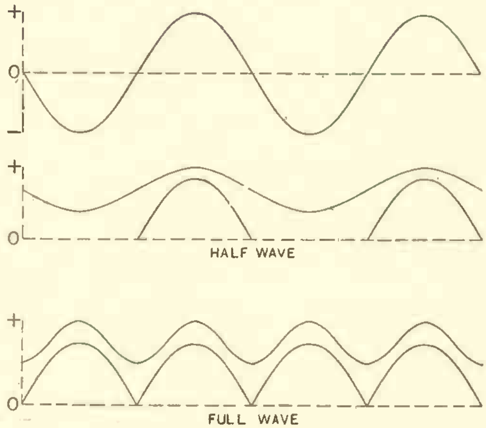


Fig. 1.—A graphical representation of an A.C. voltage or current and the relative outputs obtained from half-wave and full-wave rectifiers.

Two Supplies

In an A.C. mains receiver, using indirectly heated valves, it is necessary to have two distinct power supplies. The first is the low-tension A.C. for heating the valve cathodes, and the second is the high-tension smoothed D.C. supply for the anodes and screens of the different valves. The grid bias is usually derived from the smoothed D.C. supply, although it may be obtained from an entirely separate transformer and smoothing equipment.

The Mains Transformer

The starting-point in the two power supplies, necessary for the operation of the receiver, is the transformer. The simplest mains transformer for an A.C. receiver has three independent windings. The first is connected to the mains, while the two secondary windings give high-tension A.C. for the rectifier and low-tension A.C. for the valve heaters.

While the voltage of the high-tension secondary winding varies within wide limits, depending on the set and method of rectification, the low-tension secondary is invariably 4 volts for indirectly heated valves. Each heater of the A.C. mains valves takes 1 ampere, so that the heater winding on the transformer must be designed to give the same number of amperes as valves to which it is to supply current. The maximum permissible variation in the voltage across the heaters of A.C. mains valves is ± 5 per cent., which means that the voltage must lie between 3·8 and 4·2 volts.

Obtaining the High-Tension D.C.

The principle of obtaining the high-tension D.C. is to rectify the high voltage A.C. from the transformer and then smooth the rectified A.C. by means of chokes and fixed condensers.

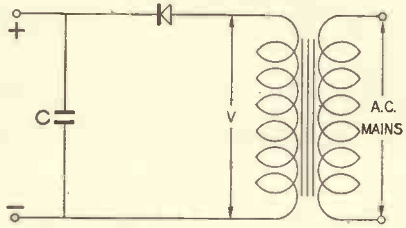


Fig. 2.—A half-wave rectifying circuit using a metal rectifier.

Types of Rectifiers

Rectifiers are divided into two categories, valve rectifiers and dry metal oxide rectifiers. The valve rectifier is similar in appearance to a receiving valve, but, unlike the latter, it has no grid. The A.C. mains are connected to the primary of a transformer having two secondary windings. One of the latter supplies A.C. to the filament of the rectifier valve. This winding has a centre tapping. The other winding is connected to the anode at one end and to the — pole of the D.C. circuit at the other. The + of the D.C. circuit is taken from the centre tapping of the filament supply winding.

The metal rectifier, unlike its valve counterpart, has no filament or heater, and is simply a permanent device for one-way current.

Methods of Rectification

There are several methods of using the valve and metal oxide rectifiers to obtain direct current from A.C. These methods are divided into two kinds, namely, half-wave and full-wave rectification. In a half-wave rectifier only one-half of the alternations of A.C. is allowed to pass the rectifier, while the reverse alternations are completely suppressed. The top curve in Fig. 1 represents an alternating voltage drawn in graphical form. In a 50-cycle supply there is one complete alternation in one-fiftieth of a second. The middle curves of Fig. 1 show what happens to the atlernating voltage after being rectified by the half-wave method. The upper wave line indicated above the two positive humps shows the nature of the direct current obtained when a reservoir condenser is connected across the output of the rectifier. This direct current is equivalent to a steady current with a superimposed A.C. at a frequency of 50 cycles per second, which is the same as that of the supply.

Full-Wave Rectification

In a full-wave rectifier both halves of the alternating supply are utilised by the rectifier. The lowest curves in Fig. 1 show the direct current as obtained from a full-wave rectifier. The upper curve indicates the nature of the direct current across the first smoothing condenser. The frequency of the ripple from a full-wave rectifier is, it will be seen from Fig. 1, double that of the A.C. supply frequency.

Half or Full-Wave Rectification ?

It is clear from the curves shown in Fig. 1 that when half-wave rectification is used the magnitude of the ripple, which has to be smoothed out, is much greater than it is for full-wave rectification.

Half-wave rectification is, therefore, preferred only for small values of D.C., up to 25 milliamperes, or where some residual hum does not matter. Since the frequency of the hum, obtained from a half-wave rectifier working on a 50-cycle supply, is 50 cycles per second also, this method of rectification is more suitable when a moving iron loud speaker is to be employed, because this frequency is not very well reproduced by this type of speaker.

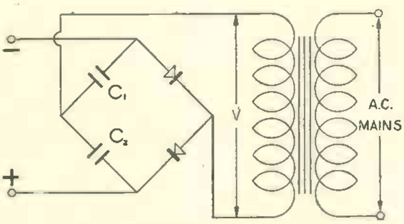


Fig. 3.—The circuit of the voltage-doubler rectifier. The two condensers, C_1 and C_2 must not exceed or be less than the specified capacity. Except in the largest Westinghouse rectifiers, these two condensers are 4 microfarads each.

The proper smoothing of a half-wave

rectifier output requires larger smoothing condensers than does full-wave, but the whole equipment of the former is cheaper than the latter.

Full-wave rectification is the commonest method of obtaining the D.C. supply in all-mains receivers, especially when the rectified current exceeds 25 milliamperes. The main objection to full-wave rectification is that the residual hum has a frequency which is more within the audible scale than when half-wave rectification is used. The residual hum of any frequency may, however, be completely removed by using a correctly designed tuned filter.

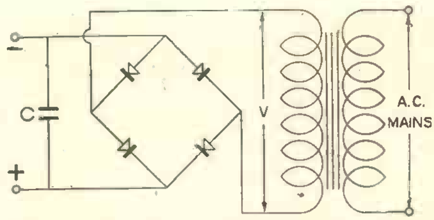


Fig. 4.—A full-wave metal rectifier circuit known as the Bridge Circuit.

Metal Rectifier Circuits

The simplest of all rectifier circuits is that shown in Fig. 2. It consists of a double-wound mains transformer, having a primary winding to suit the mains voltage, and a secondary winding to suit the capacity of the rectifier. This circuit gives half-wave rectification. The D.C. voltage output at full load across the first smoothing condenser, C, is about ·7 to ·9 times the A.C. voltage V across the transformer. The actual voltage depends on the type of rectifier.

The Voltage-Doubler Circuit

The most popular method of obtaining full-wave rectification with a metal oxide type rectifier is shown in Fig. 3. The circuit has the double-wound transformer, which is common to all types of rectifiers, with one exception. The rectifier has a centre-tapping which is connected to one end of the A.C. from the transformer. The other side of the A.C. is connected to the centre point of two condensers of equal capacity, which are placed across the D.C. output. This is known as the voltage-doubler circuit because the E.M.F. of the D.C. output is approximately double that of the A.C. input. Actually, on full load the D.C. output from a voltage-doubler type of rectifier is between one and a quarter to one and three-quarter times the A.C. voltage input. The chief advantage of this type of rectifier is that a comparatively low A.C. voltage is required, which reduces danger and insulation difficulties to a minimum.

The Bridge Circuit

Fig. 4 shows the circuit of a bridge-connected metal rectifier. This gives a full-wave output at a voltage somewhat less than that of the A.C. voltage across the transformer. This circuit has the disadvantage that it is more expensive than the voltage doubler type, because more rectifier units are necessary.

Valve Rectifier Circuits

The circuit of a half-wave valve rectifier is shown in Fig. 5. The mains transformer has two secondary windings. The high-tension winding V has a voltage about the same as that of the D.C. output across the condenser C. The positive of the D.C. supply is obtained from the centre tapping of the filament heating winding of the transformer. This is the simplest valve rectifier circuit for valves having low-tension filaments.

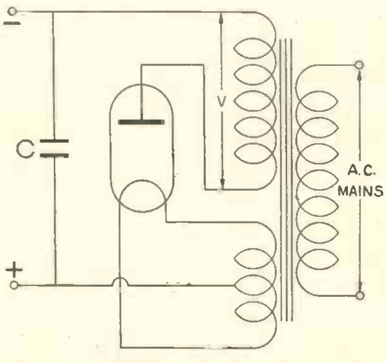


Fig. 5.—The circuit of a half-wave valve rectifier using a directly heated thermionic valve.

Valve Rectifier without Transformer

Fig. 6 shows the half-wave rectifier circuit of a valve having a filament heater suitable for the full mains voltage. The cathode of the valve is indirectly heated as indicated in the diagram. This type of valve, the Ostar-Ganz, considerably simplifies the equipment of an A.C. mains set where the mains voltage is high enough to obviate the transformer. Receiving valves of the mains voltage heater type are also made, which enable an A.C. set to be designed without a transformer.

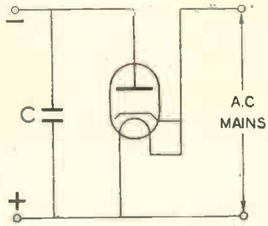


Fig. 6.—A half-wave rectifier circuit using an Ostar-Ganz valve. This valve has a mains voltage filament, which renders a transformer unnecessary.

Full-wave Valve used as Half-wave Rectifier

Half-wave rectification can be obtained from a valve designed for full-wave working if the two anodes are connected together, as shown in Fig. 7. If a full-wave valve rectifier is used in this way, the same D.C. current may be passed through the valve as when it is used as a full-wave rectifier. The D.C. voltage output obtained from this type of rectifier is about the same as the A.C. voltage V.

Full-wave Valve Rectifier

The most popular of valve rectifier circuits is shown in Fig. 8. The high-tension secondary winding of the transformer is centre-tapped. This centre-tapping gives the negative of the D.C. supply, while the centre-tapping of the filament winding gives the positive of the rectified current. The full-load D.C. voltage output of this type of rectifier is about the same or slightly in excess of the A.C. voltage V across half the H.T. secondary of the transformer.

Indirectly Heated Rectifiers

When a directly heated rectifying valve is used to supply high tension current to indirectly heated receiving valves, the rectifier heats up first and applies the full voltage to all the valves in the set. This happens because the receiving valves do not pass any current for at least thirty seconds after switching on, consequently the chokes and voltage reducing resistances are ineffective. This arrangement of valves necessitates using high voltage condensers throughout the set, which makes the equipment expensive. A directly heated rectifier is a particular source of danger when the full D.C. output unloaded is much in excess of the maximum at which the valves are designed to work.

This serious objection is overcome if the rectifying valve also has an indirectly heated cathode. The circuit of a full-wave indirectly heated rectifier is shown in Fig. 9. The cathode is connected internally to one end of the heater, so that this type of valve has four base pins, and not five like the receiving valves of this type. It will be noticed from the diagram that the centre-tapping of the heater winding is unnecessary when an indirectly heated rectifier is used. As might be expected, the characteristics of indirectly heated rectifiers are better than those of the directly heated type.

The use of an indirectly heated rectifier is unnecessary when a directly heated output valve is used in the set, because this valve heats up at the same rate as a directly heated rectifier, and effectively prevents any stress on the other valves or components in the set.

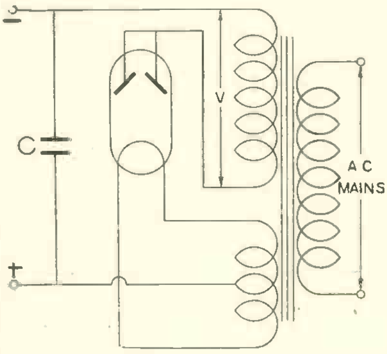


Fig. 7.—How to use a full-wave rectifying valve as a half-wave rectifier. The two anodes are connected in parallel.

Valve or Metal Rectifier ?

Now that metal rectifiers are cheaper than when they were first introduced, there is very little to choose between the two types of rectifiers. The metal rectifying equipment is slightly more expensive and less efficient than the valve type. The impedance of the metal rectifier is higher than that of the valve, consequently the voltage regulation is not so good. By voltage regulation is meant the difference between the full-load and no-load D.C. output. This is not a serious objection, because the regulation can always be allowed for in the design of the complete set. The metal rectifying equipment takes up more baseboard space than that of the valve rectifier. The chief advantage of the metal rectifier is that it is more lasting and robust than the valve.

Smoothing the Rectified D.C.

The rectified D.C. obtained across the condenser C, shown in the diagrams (Figs. 2-9), has a large ripple and requires additional smoothing before it is suitable for the high-tension and grid-bias supply of the receiving valves. Fig. 10 shows the simplest form of smoothing circuit which is used after the first reservoir condenser. The choke CH and condenser C_1 provide sufficient smoothing for the high-tension supply of the output valve, and, in order that the anode of this valve can be connected at this point without additional voltage absorbing apparatus the smoothed output of the rectifier across A—B is arranged to be suitable for the output valve.

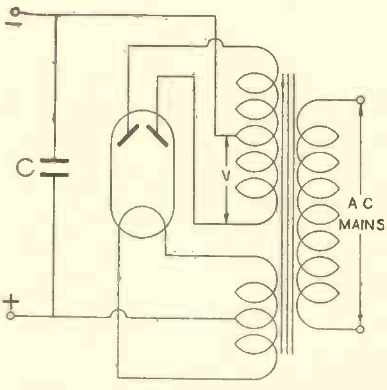


Fig. 8.—The circuit of a full-wave valve rectifier using a directly heated valve.

Obtaining Different Voltages

The valves preceding the output stage generally require a lower high-tension voltage. The necessary adjustment in voltage is obtained by resistances connected in the valve anode circuits, as shown in Fig. 10. Besides reducing the voltage of the high tension, these resistances have two other purposes. In conjunction with the condenser C_2, the resistance R gives additional smoothing, and serves to decouple the anodes of the various valves from one another. Each valve preceding the rectifier must have a similar condenser and resistance in its anode circuit in order to prevent interaction between the various amplifying stages. The calculation of the resistances to give the required anode voltages is given when dealing with the example designs.

Smoothing and Decoupling Condensers

There are two distinct types of fixed condensers which are used for smoothing and decoupling purposes. The first is the paper dielectric condenser and the second is the electrolytic type. The electrolytic type is to be preferred for the larger values of capacity because they are more compact. The important point to remember when using electrolytic condensers is that they must be connected with the positive terminal to the positive side of the high-tension supply. If an electrolytic condenser is connected the wrong way round, damage to the condenser and rectifier will result. Electrolytic condensers are not suitable for use in the voltage doubler rectifier circuit shown in Fig. 3.

Condenser Working Voltage

The rated working voltage of a condenser must never be exceeded. The working voltage stated by the manufacturer is the peak voltage, not the R.M.S. pressure. The first smoothing condenser has to stand a voltage nearly one and a half times the maximum D.C. voltage output of the rectifier. Thus, a rectifier having a maximum D.C. output of 250 volts would have a smoothing condenser rated at 375 volts working. Sometimes the test voltage of the condensers is given instead of the working voltage. This is misleading, because some manufacturers specify a working pressure of one-third that of the test voltage, while others recommend a working voltage half that of the test. Condensers are normally made for 200, 250, 375, 400, 500, 750, 800 volts D.C. working pressure and higher values for big amplifiers.

The Rating of Resistances

Resistances are usually rated to dissipate so many watts. After the value of the resistance required in a particular circuit has been calculated, its rating is estimated from the following :—

$$W = \frac{E^2}{R},$$

where W = rating of the resistance in watts.
E = voltage absorbed by the resistance.
R = resistance in ohms.

Suppose a resistance is to absorb 100 volts and the resistance required to do this is 5,000 ohms, then,

$$W = \frac{100^2}{5,000}$$
$$= 2 \text{ watts.}$$

Chokes

The inductance of smoothing chokes is usually 20–50 henrys. The larger value is used for amplifiers taking up to 120 milliamperes D.C., while 30 henrys in conjunction with a 4-microfarad condenser is sufficient for most sets. A choke is rated at a particular inductance at a specified current. It is the property of an iron-cored choke that its inductance decreases as the D.C. polarising current increases. It is, therefore, essential to see that the high-tension current passing through a choke is not exceeded, or hum will result through the lowering of its inductance below an effective value.

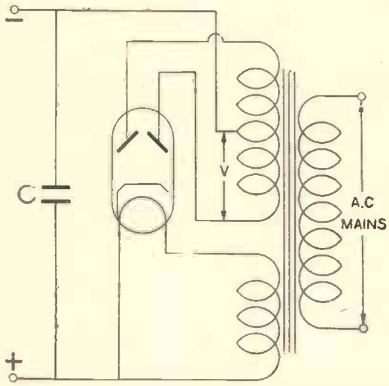


Fig. 9.—The circuit of a full-wave rectifier using an indirectly heated cathode valve.

It is not usual to have more than one smoothing choke in a complete A.C. receiver.

Calculation of Screen Potentiometers

The voltage applied to the screen of a screened-grid amplifying valve is very much below that necessary for the anode. Moreover, the current taken by the screen is not uniform over a number of valves. Therefore the method of absorbing the excess voltage shown in Fig. 10 is not suitable, because a slight change in screen current from the estimated value would give a screen voltage much in excess or below that required.

When the screen voltage is not to be made variable, the potentiometer circuit, shown in Fig. 11, is used. The calculation of the values of the two resistances R_1 and R_2 is not so straightforward as for the anode resistances of the triode valves. The following formula :—

$$R_1 = \frac{E_2}{\dfrac{V}{R_1 + R_2} + I_s}$$

where R_1 = Resistance of positive half of potentiometer.
R_2 = Resistance of negative half of potentiometer.
E_2 = Volts to be dropped by R_1.
V = Voltage across $R_1 + R_2$.
I_s = Current taken by screen (amps.).

The proof of this formula is an interesting application of Ohm's Law, where

$$I = \frac{E}{R} \text{ or } E = IR.$$

Let I_1 = potentiometer current with screen disconnected,

then

$$I_1 = \frac{V}{R_1 + R_2} \quad . \quad . \quad . \quad (1)$$

When the valve screen is connected, the voltage E_2 dropped by R_1 is given by

$$E_2 = R_1 (I_1 + I_s) \quad . \quad . \quad . \quad . \quad (2)$$

Since I_1 is known in terms of data available, the expression for I_1 in formula (1) is substituted in (2), then

$$E_2 = R_1 \left(\frac{V}{R_1 + R_2} + I_s\right), \text{ or}$$

$$R_1 = \frac{E_2}{\dfrac{V}{R_1 + I_2} + I_s}$$

Consider a practical example in which the line voltage V is 250 and the screen voltage is to be 75 volts, with screen current 2 milliamperes.

First of all it is necessary to decide on a suitable value for $R_1 + R_2$, the total potentiometer resistance. It is usually sufficient to pass 5 milliamperes through the potentiometer; more, of course, gives a higher degree of accuracy in screen voltage should the screen current be different from the average. The total potentiometer resistance for a current of 5 milliamperes is therefore given by

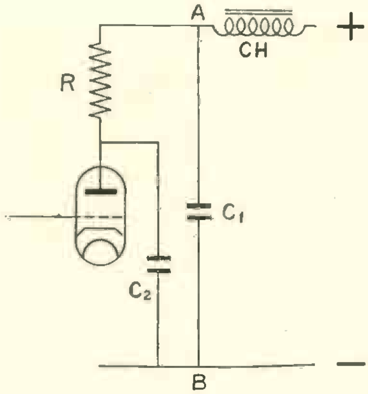


Fig. 10.—A portion of an A.C. mains receiver showing the method of smoothing and adjusting the voltage of the rectified current.

$$R_1 + R_2 = \frac{250}{5} \times 1{,}000$$
$$= 50{,}000 \text{ ohms.}$$

If the screen voltage is to be 75 volts, the voltage dropped by R_1 is 250 − 75 volts = 175 volts. Therefore

$$R_1 = \frac{175}{\frac{250}{50{,}000} + \frac{2}{1{,}000}} \text{ ohms.}$$
$$= 25{,}000 \text{ ohms.}$$

The potentiometer in this example will, therefore, consist of two equal resistances of 25,000 ohms each.

DESIGN FOR 3-STAGE A.C. RECEIVER

The circuit shown in Fig. 12 is a typical three-stage receiver employing variable-mu high-frequency amplifier, leaky grid detector and pentode output stage.

The valves to be used are Mullard MM4V., variable-mu H.F., Mazda AC/2HL detector and Mazda AC/PEN output valve.

It is essential in the design of a mains receiver to settle the valves first, because the calculation of all the resistances and design of the rectifying equipment is relative to them. The characteristics of different types of valves varies widely, and once a set has been designed for a particular combination of valves it is not possible to substitute others. Now that mains sets are more popular, the different types of valves are available in more than one make with approximately the same characteristics.

The Total H.T. Current

The first step in the design of a mains receiver is to estimate the total high-tension current. The current taken by the individual valves is found in the data supplied by the manufacturers. The greatest proportion of the high-tension current is taken by the output valve. At the maximum anode voltage, 250, the AC/PEN valve takes 30 milliamperes, plate or anode current, and 5 milliamperes screen current at 200 volts on the screen. The grid-bias voltage under these conditions is 10 volts. The total current for this valve is therefore 35 milliamperes.

The detector valve working at 100 volts will take about 5 milliamperes. When a valve is to be used as a leaky grid detector, the maximum anode voltage is not required.

For the variable-mu screen-grid valve there are three values of high-tension current to be estimated. They are the anode current, screen current and screen-potentiometer current. The screen potentiometer consists of two resistances, $R_1 + R_2$, when R_3 is set at zero, *i.e.*, maximum volume or minimum grid bias. Since the calculation of the several resistance values for screen-grid valves of this type necessitates actual measurements, the manufacturers supply the requisite data. With a maximum H.T. voltage of 250, R1 is

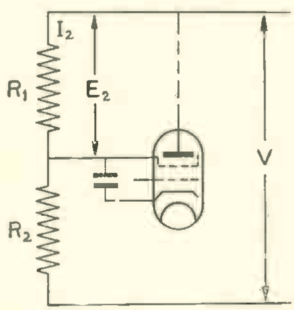


Fig. 11.—Part of the circuit of a mains screen-grid valve showing the potentiometer method of obtaining the screen volts.

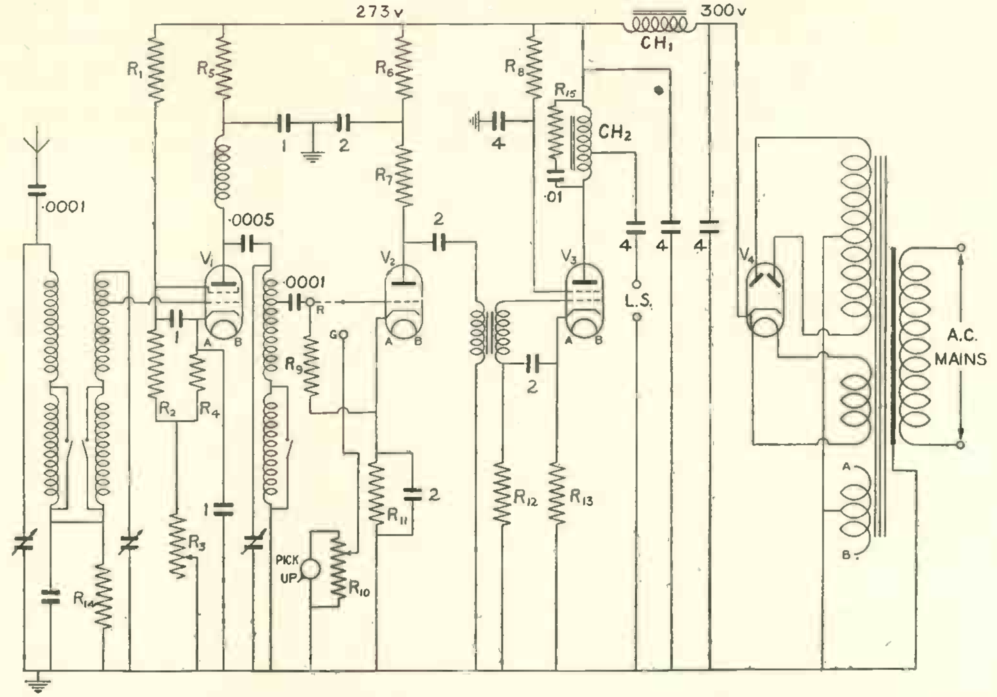


Fig. 12.—The complete wiring diagram of a 3-stage A.C. mains receiver. The mains transformer has two 4-volt secondary windings and a high tension secondary of 250 + 250 volts. The capacity of the condensers is in microfarads. The following are the values of the various resistances :—

R_1 = 27,000 ohms.	R_6 = 20,000 ohms.	R_{11} = 500 ohms.
R_2 = 20,000 ,,	R_7 = 15,000 ,,	R_{12} = ·1 megohm.
R_3 = 10,000 ,,	R_8 = 15,000 ,,	R_{13} = 300 ohms.
R_4 = 200 ,,	R_9 = ·25 megohm.	R_{14} = 1,000 ,,
R_5 = 12,000 ,,	R_{10} = ·1 megohm potentiometer.	R_{15} = 15,000 ,,

25,000 ohms and R2 is 20,000 ohms for this particular valve. Therefore, the potentiometer current is

$$I_p = \frac{250 \times 1{,}000}{20{,}000 + 25{,}000}$$

maximum = 5·5 milliamperes.

The screen current is about 1·5 milliamperes, and the anode current at minimum grid bias is 6 milliamperes. The total high tension required for this valve is therefore 5·5 + 1·5 + 6 = 13 milliamperes. Now that the individual valve currents are known, the total is found by adding the results together. The total current required is therefore 35 + 5 + 13 = 53 milliamperes.

The Rectifying Valve

Since all the valves are of the indirectly heated type, a similar kind of rectifying valve is desirable to safeguard the set. A valve to suit these requirements is the Micromesh R.1. By referring to the maker's curves of this valve it is seen that with an A.C. input voltage of 250 + 250 volts a D.C. output of 300 volts at 53 milliamperes is obtained. This allows 50 volts to spare between the rectifier and the anode of the first valve. This is ample.

Adjusting the Pentode Voltages

The voltage obtained from the rectifier must be reduced to 250 volts across the anode and cathode of the A.C. pentode output valve. Since the grid bias is to be obtained by the inclusion of a resistance R13 in the cathode lead, the drop, 10 volts, across this will be subtracted from the H.T. supply. The voltage drop to be obtained between the rectifier positive and the anode is therefore 40 volts. This is done by choosing the two chokes, CH1 and CH2, of suitable ohmic resistance to do this. The resistance required to drop a given voltage, E, is given by

$$R = \frac{E \times 1{,}000}{I\ m.a.}\ \text{ohms, or}\ E = \frac{R \times I}{1{,}000}\ \text{volts.}$$

There must be two calculations for this resistance, because the current in CH1 is not the same as that in CH2. Suppose a suitable output choke is chosen first. This could be an R.I. Pentomite multi-ratio choke, which has a D.C. resistance of 450 ohms. The current passing through this component will be 30 milliamperes. Therefore the voltage drop across this will be

$$E = \frac{450 \times 30}{1{,}000}$$
$$= 13{\cdot}5\ \text{volts.}$$

It is evident that the extra 26·5 volts must be dropped by the main smoothing choke CH1, which carries 53 milliamperes. The resistance of this choke must be, therefore,

$$R = \frac{26{\cdot}5 \times 1{,}000}{53}$$
$$= 500\ \text{ohms.}$$

The resistance of this choke could be increased up to 600 ohms with a loss of only 5 volts extra, which would not matter. The resistance must not be lower than 500 ohms or the valve will be overrun.

Pentode Grid Bias

The total current passed through the pentode is the screen current plus the anode current. This current, 35 milliamperes, passes through the resistance R13 (Fig. 12). Since the lower end of this resistance is connected to earth, the current flowing through it causes the cathode to be at a positive potential with respect to earth. If the grid is returned to earth by a D.C. conducting path, the grid will then be negative with respect to the cathode.

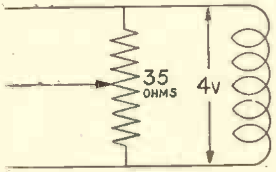


Fig. 13.—The method of obtaining the electrical centre of a valve filament or heater winding of a mains transformer when a centre tapping is not provided.

The calculation of grid-bias resistances is similar to that for anode resistances. For the pentode 10 volts is required for grid bias. Thus,

$$R = \frac{E \times 1{,}000}{I\ m.a.}\ \text{ohms.}$$
$$\therefore R = \frac{10 \times 1{,}000}{35}$$
$$= 286\ \text{ohms.}$$

The nearest standard resistance to this valve is 300 ohms, which gives a drop of 10·5 volts, which is as near to the correct value as the accuracy of the resistance or valve current is likely to be.

Pentode Screen Voltage

The maximum voltage on the screen of the AC/PEN valve is 200 volts. The difference between the smoothed voltage and the screen volts is 273 − 200 = 73 volts. The current taken by the screen is 5 milliamperes. As before

$$R = \frac{E \times 1{,}000}{I\ m.a.}$$
$$\therefore R8 = \frac{73 \times 1{,}000}{5}$$
$$= 14{,}500\ \text{ohms.}$$

A resistance of 15,000 ohms is therefore used for R8.

Detector Anode Voltage

There are two resistances, R6 and R7, in the anode circuit of the detector, or gramophone pick-up input, valve.

The purpose of R6 is decoupling in conjunction with the 2-microfarad condenser connected to the lower end of it. R7 is to provide a feeding resistance for the intervalve transformer. Voltage to be dropped by R6 + R7 is 273 − 100 = 173 volts, and the current passed when the valve is working as a detector is 5 milliamperes. The total resistance of R6 + R7 is therefore

$$R6 + R7 = \frac{173 \times 1{,}000}{5}$$
$$= 35{,}000\ \text{ohms, approximately.}$$

This would be split up into 20,000 ohms for R6 and 15,000 ohms for R7.

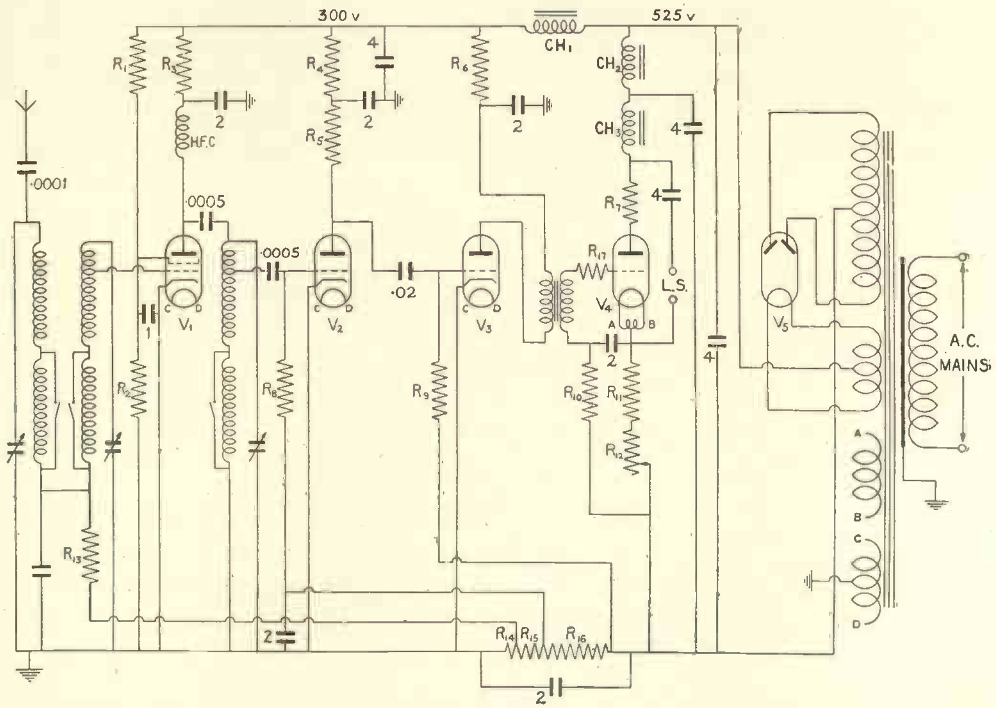


Fig. 14.—The complete wiring diagram of a 4-stage A.C. mains receiver using a directly heated output valve. The capacity of the condensers is in microfarads. The following are the values of the various resistances :—

R_1 = 35,000 ohms.	R_6 = 4,000 ohms.	R_{10} = ·25 megohm.	R_{14} = 40 ohms.
R_2 = 25,000 ,,	R_7 = 100 ohms.	R_{11} = 1,500 ohms.	R_{15} = 100 ,,
R_3 = 12,500 ,,	R_8 = ·5 megohm.	R_{12} = 500 ,,	R_{16} = 710 ,,
R_4 = ·1 megohm.	R_9 = ·25 megohm.	R_{13} = 2 megohms.	R_{17} = ·1 megohm.
R_5 = 50,000 ohms.			

Radio Gram Switch

A switch is shown in the grid circuit of V2 (see Fig. 12). When the switch is in position R, as shown, the grid is connected to the H.F. output from the valve V1, and also to the cathode *viâ* the grid leak R9. With the switch in position G the grid is disconnected from the radio input and is connected to the output from the gramophone. The grid is now in D.C. connection with earth and not the cathode.

Grid Bias for Pick-up Input

By arranging the switch in this way the grid of V2 is made negative with respect to the cathode by means of R11. It is now necessary to refer to the data for the AC/2HL valve. The grid bias required for this valve, when used as an amplifier, is, with 150 volts H.T., 1·5 volts. The anode current taken with this grid bias and anode voltage is about 3 milliamperes. Since the anode resistance has already been fixed for the valve when working as a detector, it is necessary to check what anode voltage will be obtained with 3 milliamperes passing through R6 and R7. As before

$$E = \frac{R \times I \text{ m.a.}}{1{,}000} \text{ volts.}$$

$$\therefore E = \frac{35{,}000 \times 3}{1{,}000} \text{ volts.}$$

$$= 105 \text{ volts.}$$

The voltage on the anode will therefore be about 170 volts, which is near enough.

The value of the bias resistance R11 is

$$R11 = \frac{1{\cdot}5}{3} \times 1{,}000$$

$$= 500 \text{ ohms.}$$

The Variable-Mu Valve Voltages

There are five voltage adjusting resistances used in the circuits of this valve.

R5 is used for the adjustment of the anode voltage. This has to drop 73 volts, since the maximum anode voltage of a MM4V valve is 200 volts. Therefore

$$R5 = \frac{73}{6} \times 1{,}000$$
$$= 12{,}000 \text{ ohms.}$$

R4 is the resistance which gives a bias of 1·5 volts to the grid, when R3, the variable biasing resistance, is set at a minimum. This resistance passes the maximum anode current of 6 milliamperes plus the maximum screen current of 1·5 milliamperes. Therefore

$$R4 = \frac{1{\cdot}5}{7{\cdot}5} \times 1{,}000$$
$$= 200 \text{ ohms.}$$

The resistances, R1 + R2 + R3, form the potentiometer for obtaining a constant screen voltage with a variable screen current. As R3 is decreased the grid bias is decreased also. This causes an increase in screen current. The ratio of the voltages across R1 and R2 + R3 is kept approximately the same, because as the screen current in R1 causes an extra drop therein, the lower half, R2 + R3, is decreased also. The values of these three resistances for the circuit are as follows :—

R1 = 27,000 ohms.
R2 = 20,000 ohms.
R3 = 10,000 ohms, variable.

The grid of the MM4V valve is in D.C. connection with earth *viâ* the tuning coil and resistance R14. R14 is 1,000 ohms. The value of this resistance is not important so long as it is not low enough to affect the working of the band-pass coupling condenser.

4-STAGE RECEIVER WITH SUPER POWER OUTPUT

The circuit diagram of this receiver is shown in Fig. 14. It is different in many respects from the three-stage receiver just described. With the full anode voltage of 400 volts on the anode of the output valve, a maximum speech output of 5 watts, undistorted, is obtainable.

A suitable combination of valves for this circuit is as follows :—

V1, Mazda AC/SG, H.F. amplifier.
V2, Mazda AC/2HL, anode bend detector.
V3, Mazda AC/P1, first L.F. amplifier.
V4, Mullard DO/25, output valve.
V5, Mullard DW/4, rectifier.

The Maximum H.T. Voltage

The maximum high-tension voltage required is found by adding together the anode volts and grid voltage of the output valve. This is 400 + 100 volts. The 500 volts required is obtained by using a DW4 Mullard rectifier, which is a directly heated cathode type with a filament which heats up at the same rate as the directly heated cathode of the DO/25 output valve. By using a directly heated output valve, the necessity for providing a delay in the application of the maximum H.T. is obviated to some extent.

The Total H.T. Current

The total H.T. current and the various voltages required are as follow :—

DO/25.—400 volts 60 milliamperes.
AC/P1.—200 volts 20 milliamperes.
AC/2HL.—200 volts, 1 milliampere or less.
AC/SG.—200 volts 8 milliamperes for anode.
AC/SG.—80 volts 1·5 milliamperes for screen.
Screen potentiometer, 5 milliamperes.
Total current = 95·5 milliamperes.

Output Valve Grid Bias

The usual method of obtaining the grid bias voltage for a directly heated output valve is shown in Fig. 14. This consists of a resistance, R11 + R12, connected between the centre tapping of the transformer filament winding and the negative H.T. A portion of the biasing resistance, R12, is variable, so that the anode current may be adjusted to the correct value. A variation of this kind is necessary only for larger valves, such as the one under consideration. The maximum grid bias required is 112 volts. Thus, with 60 milliamperes anode current the total resistance required is

$$R11 + R12 = \frac{112 \times 1{,}000}{60}$$
$$= 1{,}870 \text{ ohms.}$$

A total of 2,000 ohms is therefore suitable. If R11 is made 1,500 ohms and

R12 500 ohms, as recommended by the manufacturers, a variation between 90 and 120 volts is obtained.

Losing 200 Volts H.T.

A set of this kind, where the high-tension voltage of the output valve is very much in excess of that required for the preceding stages, presents a special problem in the design of A.C. receivers. The difference between the unsmoothed high-tension voltage and that required for the valve anodes is 325 volts, *i.e.*, 525 − 200. Of this 325 volts, 230 is absorbed by the choke CH1, leaving nearly 100 volts to spare for loss in the decoupling resistances. The total current taken by the first three stages of the receiver is 35·5 milliamperes. The choke CH1 must therefore have a resistance of

$$R = \frac{225 \times 1{,}000}{35{\cdot}5} = 6{,}350 \text{ ohms approx.}$$

A choke of this resistance would not be an economical product, nor is it a standard article. A smoothing choke in this position therefore would be provided with an external resistance in series to dissipate the bulk of the power.

"Free" Speaker Field Current

It is evident from the foregoing paragraph that there is sufficient power to replace the choke CH1 by the field magnet winding of a moving coil loud speaker. Since 6,500 ohms is a standard resistance for 200–250 volts speaker field magnets, this is preferable instead of a choke and resistance. By using the speaker magnet in this way, the expense of a separate rectifier, and smoothing condenser for it, is rendered unnecessary.

Grid Bias for the Other Valves

Unlike the grid bias arrangements for the circuit shown in Fig. 12, the total high-tension current of the first three stages passes through the bias resistance, R14 + R15 + R16. This is the alternative method to connecting a separate resistance in the cathode lead of each valve. It will be noticed that the grid bias for the output valve is not obtained in this way, because it would complicate the grid circuit decoupling arrangements.

The total drop required across the resistances R14 + R15 + R16 is 30 volts, which is the bias necessary for the AC/P1 valve V3. The current through this part of the circuit is 35·5 milliamperes, therefore

$$R14 + R15 + R16 = \frac{30}{35{\cdot}5} \times 1{,}000$$
$$= 850 \text{ ohms.}$$

The negative bias required for the anode bend detector is about 5 volts. This drop must be obtained across R14 + R15, therefore

$$R14 + R15 = \frac{5}{35{\cdot}5} \times 1{,}000$$
$$= 140 \text{ ohms.}$$

Finally, 1·5 volts bias is required from R14 for the grid of the AC/SG valve V1. This resistance is 42 ohms, say 40 ohms, which is near enough. The various sections of the bias resistance for the first three stages of this receiver are therefore as follow :—

R14 =	40	ohms
R15 =	100	,,
R16 =	710	,,
Total	850	,,

There is an objection to this method of obtaining grid bias, because the failure of one of the valves to pass its anode current results in a change in the grid bias voltage of the other valves, which may be dangerous. The chief feature of this type of grid bias in mains receivers is that decoupling is necessary in each of the grid circuits. This is done with resistances R13, R8 and R9, in conjunction with two condensers of 2 microfarads each.

Working Voltage of Condensers

The working voltages of the smoothing condensers must be chosen with regard to their positions in the circuit to effect the greatest economy. The working voltage of the three 4-microfarad condensers between V4 and V5 must be 800 volts D.C., to withstand the peak voltage of the rectifier. The remainder of the smoothing and mica coupling condensers are 500 volts D.C. working. This working voltage must be specified, because 500 volts is applied to these condensers before the first three valves heat up.

LOUD SPEAKERS

By L. D. MACGREGOR

THE VARIOUS TYPES IN USE

EVER since man produced the first loud speaker he has found the subject to be a fascinating one, and even, on certain occasions, one which cannot be got away from. This being the case, I feel that under the circumstances no apology is required when introducing this subject.

Considered from the radio and amplifier point of view, loud speakers may be classified under four main heads :—

(1) ELECTRO-MAGNETIC, which includes speakers having reeds or diaphragms driven by electro-magnets.

(2) MOVING COIL TYPE, which includes all speakers where a coil of wire moving in a magnetic field constitutes the driving element.

(3) ELECTROSTATIC, or condenser loud speakers, in which the sound is produced by a diaphragm which in itself constitutes, or is part of, one plate of a condenser.

(4) VARIOUS SPEAKERS which do not come directly under any of the previous headings. Amongst these are many little-known types.

THE ELECTRO-MAGNETIC

This group may be subdivided into two main types—(*a*) the horn type, and (*b*) the "cone" type. The essential parts of the horn type are the electro-magnetic system with diaphragm or reed-driven diaphragm, the pressure chamber, the throat and the horn. This is illustrated in Fig. 1.

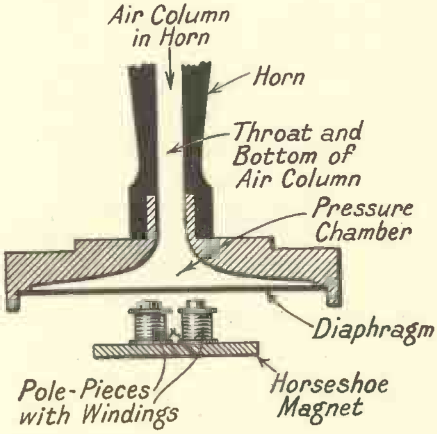


Fig. 1.—DIAGRAM SHOWING ESSENTIAL PARTS OF HORN TYPE WITH ELECTRO-MAGNETIC DIAPHRAGM.

The action of this type is familiar to most readers. The varying currents, due to speech and music, passing through the windings on the pole pieces will alternately weaken and strengthen the magnetic force on the diaphragm, causing it to move, and in doing so alternately compress and decompress the air in the pressure chamber, pushing the air in and out of the throat. Since the throat is small, the velocity of the air will be greater in it than in the pressure chamber. This pressure affects the air column in the horn, and it is by virtue of this increased velocity that we obtain the magnification with a horn. This can be easily observed by removing and replacing the horn.

Amongst the more well-known makes of this type of loud speaker are the "Brown" and the "Amplion."

The Cone Type

In this type the main parts are the electro-magnetic system with reed drive, the cone and the suspension which holds it to the outer ring. The chassis, although exceedingly useful, is not absolutely essential to the working of the speaker, whilst a baffle—in many cases the cabinet suffices—will materially improve the quality of reproduction. This is shown in Fig. 2.

With regard to this type of loud speaker, the driving units may be classified into four main types of action: (1) The simple type employing a flat reed, as in Fig. 3; (2) shaped reed type, as in Fig. 4; (3) differential reed movement (Fig. 5); and the well-known balanced armature movement illustrated in Fig. 6.

A brief explanation of these various types of unit will doubtless be of interest to the reader.

Simple Flat Reed Type

In this variety two wound bobbins are mounted on the pole pieces attached to a horseshoe magnet. The springy reed is mounted above these pole pieces and the magnetic lines of force from the horseshoe magnet complete their path through the pole pieces and reed. The varying currents of speech and music passing through the windings vary the magnetic pull on the reed, causing it to move up and down, driving the cone, which is secured to a stem attached to the reed. The best position for the reed is found by bringing it to and from the pole pieces by means of the adjusting screw (see Fig. 3).

The Shaped Reed

A similar action takes place with a shaped reed, but in this instance greater sensitivity is claimed. A typical shaped reed unit is the Brown "Vee"—a sketch of which is shown in Fig. 4.

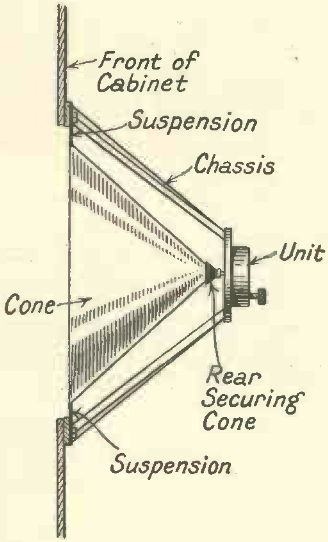


Fig. 2.—Details of an Electro-magnetic Reed.

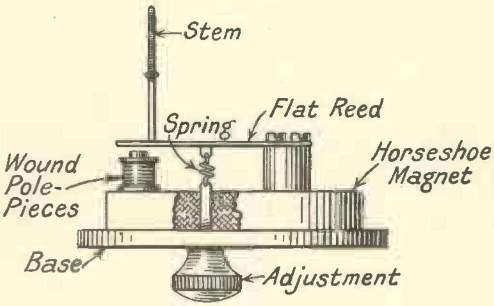


Fig. 3.—Simple Type of Driving Unit employing a Flat Reed.

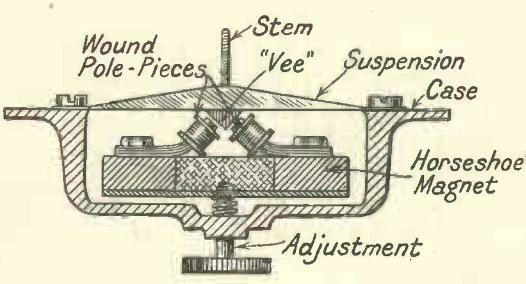


Fig. 4.—The Shaped Reed Type of Driving Unit.

The Differential Movement

This type of movement is illustrated in Fig. 5. The winding is round the reed itself, and the varying speech currents make the reed a small magnet whose tip, between the poles of the permanent magnet, alternately takes north or south polarity. In consequence, the reed is alternately attracted towards one pole, whilst it is, at the same time, repelled by the other pole. This sets up vibrations which are transmitted by the stem to the cone diaphragm.

The Balanced Armature

A typical unit of this type is illustrated in Fig. 6. It will be noted that the reed is pivoted centrally, and the windings are in two sections, one round one half and one round the other half of the reed.

The action is similar in many respects to the differential type and may, in fact, be considered as being doubly differential. Varying speech and music currents will magnetise the reed, making the ends alternately N., S. and S.N. in polarity. These ends will be alternately attracted by one of the poles near them, whilst repelled by the other at the same instant. Some form of suspension is used to maintain the reed in the normal central position, and the driving stem is sometimes connected to the reed, but more generally to the suspension.

Pole Pieces

The pole pieces are, as a rule, laminated, or built up from thin pieces, to prevent, or rather minimise, losses at the higher frequencies, although in cheaper models this refinement is often omitted.

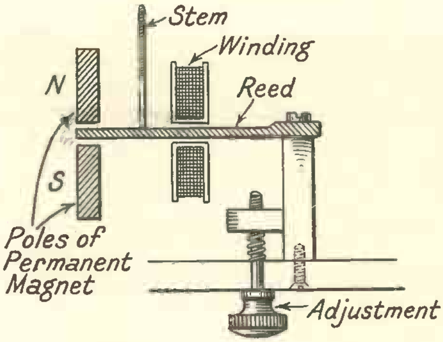


Fig. 5.—Details of the Differential Reed Movement.

Adjustment

In the types (Figs. 3, 4, 5 and 6) the adjustment will compensate for forces, such as pressure from the diaphragm and from steady current through the windings where the speaker is directly connected in the output valve anode circuit.

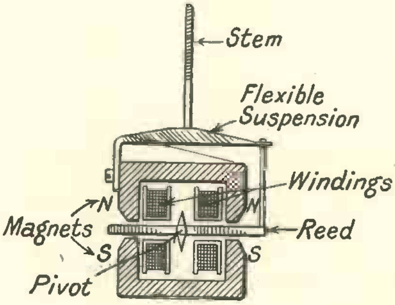


Fig. 6.—The Balanced Armature Movement.

Effect of Anode Current

Apart from the undesirable effect of the anode current in putting a bias pressure on the reed, due to the magnetism caused by it, it should be borne in mind that, in view of the bobbin size, only fine wire is used in general to wind the bobbins with. This wire is rated to carry a certain amount of current, and readers should ascertain whether this unit will stand up to the anode current — plus speech current—it is likely to meet with in practice. Should this current be in excess of the amount the unit will stand, and in all cases of doubt, it is advisable to use choke or transformer coupled output, as illustrated in Fig. 8.

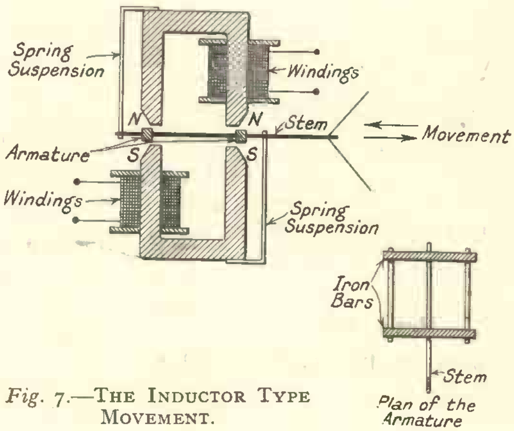


Fig. 7.—The Inductor Type Movement.

The Cone

For each type of unit there is a cone which will give the most satisfactory results, and many manufacturers state which is the correct type and size to use with their units.

Really good reproduction can be obtained from a well-designed cone speaker, and the reed-driven cone speaker has an advantage over the moving coil type in that, unless a first-class moving coil speaker is used for comparison, the cone speaker will win on sensitivity.

The Amplion "Lion" speaker, due to Dr. N. W. McLachlan, is an example of what can be secured with first-class design in the way of cone loud speakers.

Before passing to the moving coil type, it will be worth while considering the inductor type of loud speaker, which appears to be the link between the reed-driven cone and the moving coil types.

The Inductor Loud Speaker

This is shown diagrammatically in Fig. 7. The armature, consisting of two iron bars bolted together with the driving stem between them, is suspended by means of springs between two magnet systems. It will be noted that the iron bars are just clear of the pole pieces. The windings are placed as shown and suitably connected together. The principle of operation is as follows: Varying speech currents cause alternate sets of poles to exercise the greater pull on the armature, with the result that it will vibrate in a direction parallel to the pole faces, or left and right in the sketch (Fig. 7),

A typical speaker of this type is the G.E.C. inductor dynamic loud speaker.*

THE MOVING COIL

This type of loud speaker (Fig. 9A), has deservedly achieved wide popularity in the last few years, and consists essentially of an electro-magnetic pot, or permanent magnet, having a centre pole piece (*a*), a coil of wire on a former (*b*), held in position by a centreing device (*c*), and driving a diaphragm (*d*), to which it is secured. This diaphragm (*d*) is attached to a surround or suspension (*e*), the outer edge of which is held by a wooden ring (*f*) bolted to a chassis (*g*) and to a suitable baffle board (*h*). The chassis is in turn bolted to the pot or magnet. Fig. 9A illustrates this, whilst in Fig. 9B the front of the pot or magnet is shown, together with the position of the moving coil or speech coil. A sectional view is shown in Fig. 9C.

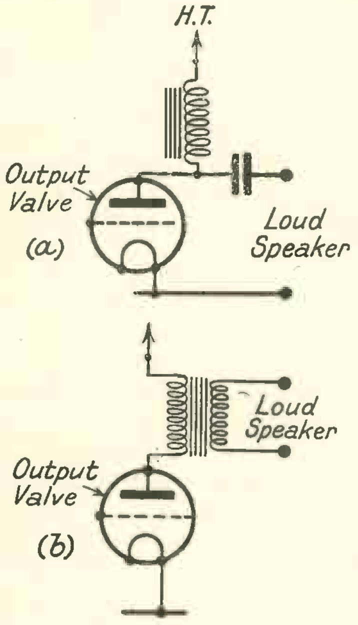


Fig. 8.—If the Anode Current is greater than the Unit will stand up to, it is advisable to use Choke or Transformer-coupled Output.

(Top). Details of choke-coupled output.

(Bottom). Details of transformer-coupled output.

According to the direction of the various speech currents flowing through the coil it moves in and out of the gap, driving the diaphragm with it.

High Resistance and Low Resistance

Broadly speaking, there are two types of coil—high and low resistance. Low-resistance coils are much more robust than high-resistance coils, are more easily constructed and, in general, present less difficulties than high-resistance coils. For this reason they are more commonly met with in commercial practice. Low-resistance coils almost invariably require a step-down ratio transformer, and many manufacturers are supplying suitably tapped transformers for such purpose with their loud speakers. High-resistance coils are generally wound to suit the output they are intended to operate from, and should be coupled to the receiver by choke coupling (Fig. 8). The practice of connecting a high-resistance speaker directly in the anode circuit of the last valve will, in cases where the anode current is fairly large, eventually lead to a breakdown of the speech coil windings.

Where moving coil speakers are used with large outputs, such as is the case with talkie and public address equipment, special attention has to be paid in the design to secure adequate strength and quality.

The moving coil loud speaker, designed by Dr. N. W. McLachlan in 1926, being a replica of the one he demonstrated to the Radio Society of Great Britain early in that same year, and now in the Kensington Science Museum, is an example of a really good speaker of this type.

Moving Coil Horn or Trumpet Speakers

It frequently occurs that it is desirable to direct the sound from a group of loud speakers towards some particular spot, such as is the case in public address and talkie work. In these instances moving coils are employed with horns or trumpets.

* Described in *Wireless World*, Nov. 18th, 1931.

The principle employed is similar to that shown in Fig. 1, except for the fact that the pot and moving coil replace the electro-magnetic system.

A typical horn loud speaker having a moving coil driving unit is that manufactured by the Western Electric Co.

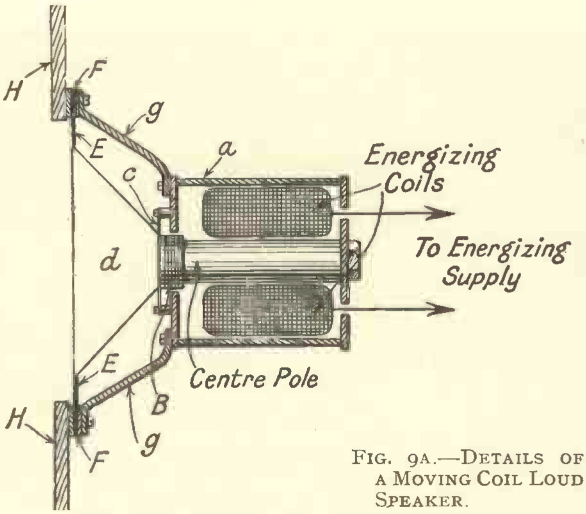


FIG. 9A.—DETAILS OF A MOVING COIL LOUD SPEAKER.

Dual or Balanced Loud Speakers

In spite of all efforts, it has been found practically impossible to obtain a single loud speaker to cover effectively the complete audio-frequency range, up to 10,000 or 15,000 cycles per second, and to give an even response over this band.

With a view to overcoming this difficulty, dual or balanced, sometimes called compensated, loud speakers have been introduced, and it is quite possible that, in the near future, even three may be employed, each speaker taking care of its own section of the audio-frequency band. This arrangement is, to an extent, in its infancy as yet, and the indiscriminate use of two loud speakers which have not been carefully chosen and matched to the output circuit is to be deprecated.

This method has been attempted with reed loud speakers, and a unit employing this principle was described some time back in the *Wireless World*.

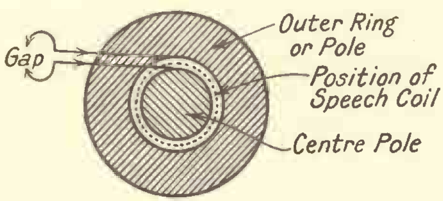


Fig. 9B.—THE FRONT OF THE POT OR MAGNET OF A MOVING COIL LOUD SPEAKER TOGETHER WITH THE POSITION OF THE MOVING COIL OR SPEECH COIL.

ELECTRO-STATIC LOUD SPEAKERS

These loud speakers are, literally, condensers in which one plate is flexible and functions as the diaphragm of the speaker, taking up varying positions according to the varying voltages impressed on it and the other plates constituting the same condenser.

An Interesting Experiment

may be conducted which will serve to demonstrate the attraction between condenser plates at high voltages.

Secure a small variable condenser of the type in which the vanes, both fixed and moving, are very thin and are separated by thin sheets of Bakelite or bakelised paper.

Fix the condenser in a vice and attach a suitable knob to the driving spindle. Next procure a testing "Megger"—preferably of the 1,000-volt type. Connect the terminals of the "Megger" to the condenser terminals, and, having persuaded someone to turn the "Megger" handle, slowly at first, then with increasing speed, rotate the variable condenser spindle backwards and forwards. It will be found that it is increasingly difficult to turn the spindle as the voltage is increased, and, if the condenser vanes are flexible enough and the separating Bakelite is very thin, the condenser will lock and the knob may

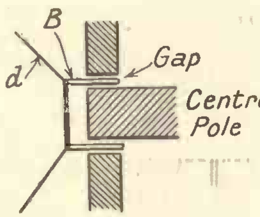


Fig. 9C.—SECTIONAL VIEW SHOWING MOVING COIL IN GAP.

be broken off without turning the spindle!

Some electrostatic loud speakers require an impressed polarising voltage in order to increase their sensitivity.

Fig. 10 shows the connections to a differential loud speaker of the electrostatic type, such as the Vogt, where a polarising voltage is employed.

An inexpensive loud speaker of this type at present available is the "Primustatic."

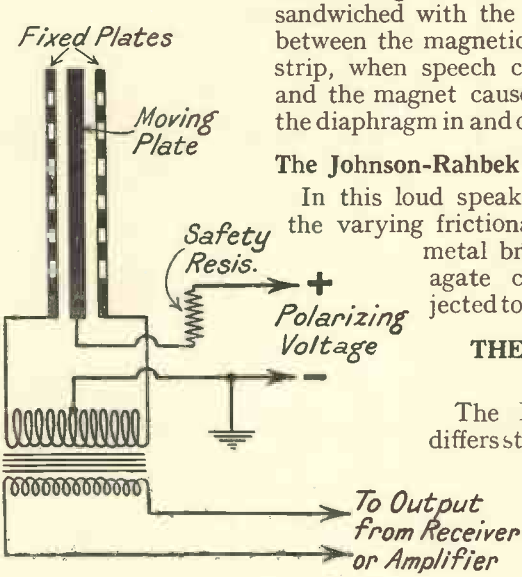


Fig. 10.—Connections for a Differential Electrostatic Loud Speaker.

VARIOUS

Siemen's Halske Metal Strip *

In this loud speaker a crinkled metal strip is suspended between the poles of a powerful electro-magnet. Speech currents, transformed down to a suitable valve, are passed through the strip, which vibrates backwards and forwards.

The Audalion †

In this speaker the drive was electromagnetic and the diaphragm was in the form of an incomplete paper cylinder free at one longitudinal edge and at both ends. It was mounted like a stool with panels inset with silk for effect.

* *Wireless World*, July 2nd, 1924.

† "Wireless Loud Speakers." Dr. N. W. McLachlan.

"Blatthaller" Siemen's Halske

The diaphragm—a flat plate of "Cellose"—has affixed to it a zig-zag copper strip on edge, which carries the speech currents. The poles of a powerful electro-magnet, alternately N. and S., are sandwiched with the strip. The reaction between the magnetic force in the copper strip, when speech currents are passing, and the magnet causes the strip to drive the diaphragm in and out, producing sound.

The Johnson-Rahbek Loud Speaker

In this loud speaker use was made of the varying frictional effects between a metal brush and a revolving agate cylinder when subjected to fluctuating voltages.

THE LANCHESTER SPEAKER

The Lanchester Speaker differs structurally from other speakers of the moving coil type. It consists essentially of a magnet assemblage, that is to say, the cobalt steel magnet with its associated pole plate and centre pole, the mechanical strength of which is employed as the basis of the whole design. Secured to the magnet assemblage is the plywood front, which in turn carries the surround supporting the speaker cone or diaphragm.

The plywood front is in effect a small baffle and has the advantage that it allows the speaker chassis to be fitted to a cabinet or baffle board without the aperture having to be adjusted to the exact size required.

Other moving coil loud speakers with special poles are the Hartley-Turner and Igranic, in which the end of the pole is chamfered.

FAULTS—THEIR CAUSE AND REMEDY

THE faults likely to be met with in general practice are many and varied. There are several which are common to practically all types of loud speakers, whilst others occur only with certain types of speaker.

Metallic Dust Round the Magnets and Pole Pieces

This fault produces all kinds of strange effects, the most common being a form of "chattering" (Fig. 11).

Nearly all loud speakers which employ

magnets of any kind are likely to gather metallic dust round their pole pieces in the course of time and, in the case of permanent magnet moving coil loud speakers, many manufacturers are providing means to minimise this trouble by protecting the rear portions of the gap with felt, rubber, or other material and, in some instances, by enclosing the magnet in a bag.

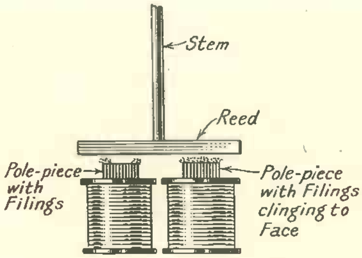


Fig. 11.—METALLIC DUST ROUND THE MAGNETS AND POLE PIECES.

This is a fault that produces many strange noises, the most common being a form of chattering.

Methods of Removing Metallic Dust

In commercial practice a powerful compressed air blower is employed, and this is, perhaps, the most satisfactory method of coping with the fault.

A vacuum cleaner, used as a blower, is useful, but even this may not prove to be entirely satisfactory.

Plasticene or modelling wax may be used, with great success, for the removal of metallic dust, the dust and filings adhering to the wax. It should be carefully removed with a blunt, non-magnetic instrument, and all final traces of it removed by the application of soft paper or a cloth.

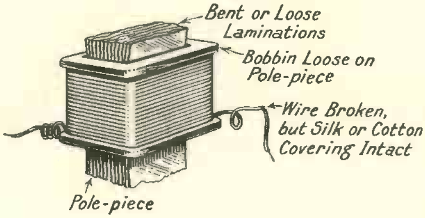


Fig. 12.—FAULTS ON THE POLE PIECES.

This may cause chattering, nasty resonances, crackling, etc.

When the Pole Pieces should be Removed

If necessary, the pole pieces may be removed, cleaned and reassembled. This is generally necessary where the pole faces have become rusted, and may be successfully accomplished with practically all forms of magnetic loud speakers. There are instances where it is advisable to send the magnet to the makers, as in the case of permanent magnets for moving coil speakers, where magnetism is definitely lost if the parts are taken down and reassembled without being re-magnetised.

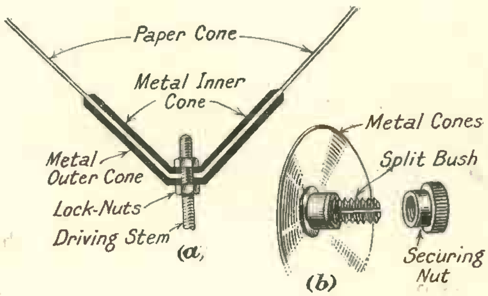


Fig. 13.—HOW THE CONE IS SECURED TO THE DRIVING STEM.

Loose lock nuts may cause chattering.

Faults on Pole Pieces

Chattering, nasty resonances, crackling, etc., are frequently due to faults on the pole pieces (Fig. 12).

Bent or Loose Laminations

These will cause chattering and unwanted resonances on certain frequencies. This may sometimes be due to the fact that the rivets which secure these laminations may have worked loose. By carefully removing the bobbin and tightening these the fault may be cured. In the case of bent laminations, these may sometimes be bent back into place, but as a rule this is not satisfactory unless they have been separated, straightened and reassembled, and the makers are the best people to whom to entrust this operation. Shellac varnish, well painted into the laminations, will often stop the trouble, but proves, as a rule, to be only a temporary expedient.

Loose Pole Pieces and Bobbins

Tighten up the pole piece securing screws after having

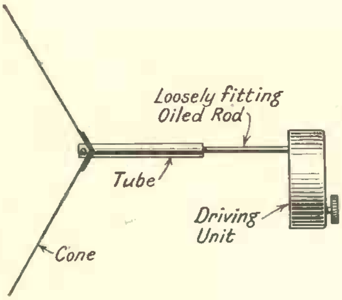


Fig. 14.—Make sure that the Securing Nut holds the Stem firmly.

correctly lined up the pole piece. In the case of loose bobbins, these may be easily cemented to the pole piece. Securing them by wedging pieces of paper between the bobbin and pole piece will be found to be only a temporary measure.

Crackling

Crackling is frequently due to a broken wire either in the bobbin or in the leads from it. It is, on occasions, the result of electrolysis taking place in the winding itself. It is, of course, presumed that the receiver has been thoroughly examined and is above suspicion, also that leads to the loud speaker are in order. Whilst the speaker is operating use two pairs of fine tweezers a short distance apart, go over all the connecting leads and ends from the bobbins, gently moving the wire backwards and forwards. When the defective spot is reached, either a noise or silence will occur. Frequently the wire becomes broken due to vibration, and the ends are held together by the covering (Fig. 12). Short-circuiting one winding at a time will determine whether the fault is in the other or not. If the fault is in the windings the bobbins may require to be rewound or replaced.

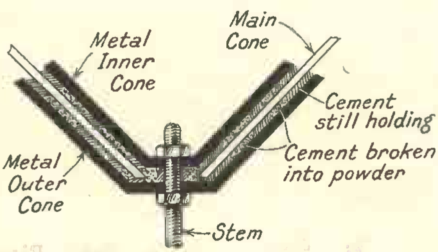


Fig. 16.—A possible cause of a "Hissing" Noise.

This may be due to the cement attaching a small metal cone to a main cone, having only adhered at certain points.

The use of excessive current through the loud speaker windings is a frequent source of trouble in this respect.

Cone Loosely Attached to Driving Stem

Two of the most popular methods of securing the cone to the driving stem are illustrated in Fig. 13, (*a*) and (*b*).

Loose lock nuts will cause "chattering," and require to be tightened in the case illustrated in (*a*).

In the method illustrated in (*b*), where a collett, or split bush having a tapered thread on it, is clamped to the driving stem, such clamping being brought about by a securing nut, the whole arrangement should be carefully examined to ensure that it does definitely *clamp* on to the stem. Should it be too large it may, when the securing nut is screwed home, merely hold the stem more or less loosely, providing a form of resilient drive which would be equivalent to that illustrated in Fig. 14.

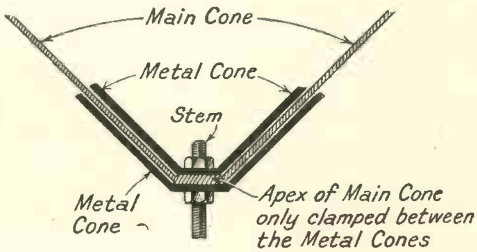


Fig. 15.—Showing how the Apex of the Cone may gather up under the Metal Clamping Wires.

Attachment of Small Metal Cones to Main Cone

These are attached as a rule in three ways :—

(1) Directly clamped to main cone.

(2) Cemented and clamped to main cone.

(3) Clamped to main cone with felt washers between the metal cone and main cone.

In each of these methods trouble may arise due to the following reasons which are illustrated, rather exaggeratedly, in Figs. 15 and 16. If, when employing

Method 1, the apex of the cone is not removed it may gather up under the metal clamping cones, as shown in Fig. 15, and prevent the secure clamping of the cone other than at its apex. This will cause noise, and the remedy is obvious.

In Method 2 the cement, if not well and evenly applied, may, in the course of time, only adhere at certain points whilst breaking away into powder in the pockets so formed and causing a sort of "hissing" noise, which is not too easy to trace. The only remedy is to remove the metal cones and, after thoroughly cleaning, to refix them. This is illustrated in Fig. 16.

In Method 3, where felt or similar washers are used between the metal clamping cones and the main cone, the felt will in time become hard or, alternatively, if in a moist place, absorb moisture,

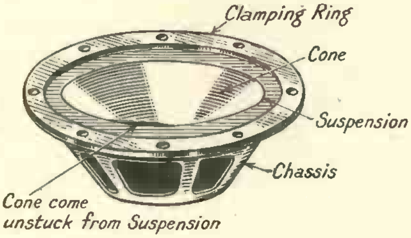


Fig. 18.—Diagram showing a Cone loose from its Suspension in places.

necessitating replacement if the speaker is to continue to function at all well.

If the felt washer be too thick the resultant effect will be similar to the effect obtained from the arrangement illustrated in Fig. 14, or to the effect obtained from attempting to drive the cone through a block of rubber. There will be a definite loss, especially in the case of some frequencies, which will depend upon the nature of the elastic coupling.

Faults in the Cone and its Surround or Suspension

A fault common to all types of cone speakers and one which frequently occurs when the speaker has been dismantled and then reassembled is that due to the cone not being perfectly central with the driving system. This will tend to put a biasing pressure on the reed or moving coil, with the result that instead of the driving force moving the coil forwards and

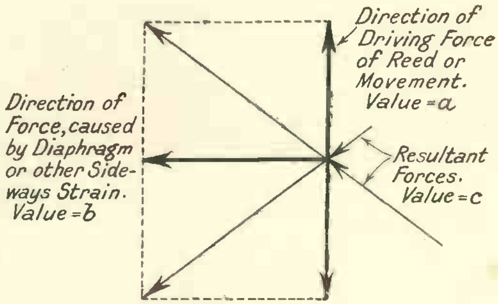


Fig. 17.—This shows the effect of a "Biasing" Force.

backwards in a line with the axis of the cone, it will, due to the biasing force, tend to drive the cone sideways, with consequent "chattering" in the case of a reed, and "grating" in the case of a moving coil. The obvious remedy is to adjust the cone position with due regard to the driving unit. The effect of the "biasing" force is illustrated in Fig. 17, which shows the well-known parallelogram of forces with the resultant force.

Cone Loose from its Suspension in Places—Suspension Torn

Another source of trouble which generally makes its presence known by "rustling," or "flapping"—a noise similar to that produced when a sheet of paper is shaken—is that due either to the cone suspension having become torn or unstuck, or to the seam of the cone having become unstuck. If unstuck, stick it down again, but if torn it may be repaired by pasting thin pieces of paper over both sides of the torn part. The writer has found that Le Page's liquid glue is one of the best materials for sticking cone seams, etc. A loose suspension may not always be readily detected, and should this be suspected it is advisable to examine the speaker carefully for this fault. A typical instance of this fault is illustrated in Fig. 18.

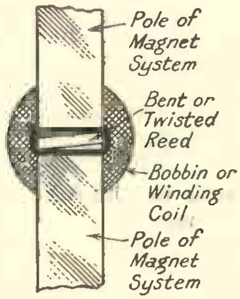


Fig. 19.—Bent or Twisted Reeds.

Bent or Twisted Reeds

This trouble is usually due to the unit having received a knock or having been maltreated in some way or other (Fig. 19). Should the bend or twist be but slight the unit will function fairly well on low power, but when power is increased the reed will hit the pole faces, due to the fact that it cannot freely travel so far as it previously could. The only remedy is to straighten the reed—a task which will require some care—or to return it to the makers for a new reed to be fitted.

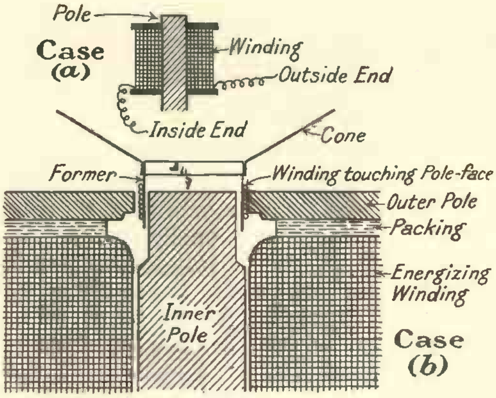


Fig. 20.—Showing how the Windings may become electrically connected to the Poles or Metal Framework, Causing a Leak to Earth.

(*a*) Reed speaker; (*b*) Moving coil speaker.

Loose or Bent Stems

Bent stems cause results like Fig. 17. If badly bent, it is wiser to fit a new stem. Most stems are either screwed or riveted to the reed, and sometimes soldered. As the reed is generally made from soft iron or other ferrous substances, it will be necessary to employ "killed spirits" when soldering to it, and it is wise, in all cases, to remove the reed before attempting to solder, as the heat will cause splashes of spirit to be thrown on to the bobbin windings, with inevitable disastrous consequences. It may be possible to protect the windings with material, but there is always an element of chance if this procedure is adopted.

Faults on the Adjustment

Should the spring fitted to the adjusting screw become inoperative due to any cause whatsoever, the result will be that the adjustment will not remain stable, and it will become necessary to remove the offending part and attend to the trouble. Rust, hardened grease, etc., often causes trouble and, on rare occasions, the spring itself may become broken.

Leakage to "Earth"

When the windings of a loud speaker become electrically connected to the poles or metal framework due to faulty or broken down insulation, the speaker is said to have a leak to earth—the metal work being considered as earth in this case. When a reed speaker produces a "whistling" sort of noise of a very high pitch this is sometimes due to leakage to earth and to H.F. reaching the loud speaker. This fault is fairly easy to trace—too easy in some instances, as in Fig. 21. Reference to Fig. 20 will illustrate the points in question. Suitable means and ways of testing are described elsewhere, and a test is made for circuit between the pole piece and the windings (Fig 20 (*a*)). By observing whether the current is greater between the outside or inside end and the pole piece an idea of whereabouts the leak is taking place may be obtained. Reinsulate or fit new windings.

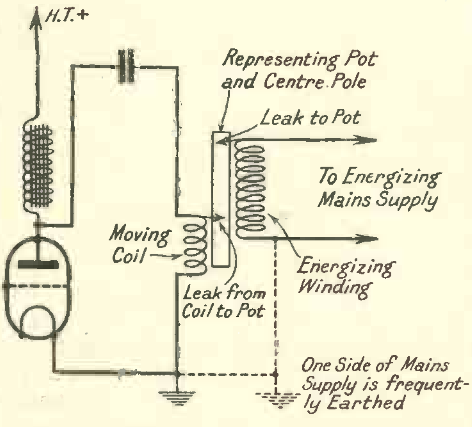


Fig. 21.—The resultant circuit of a leak between energising winding and pot and moving coil winding and pot.

Leakage from a Moving Coil Winding

In the case of a moving-coil loud speaker (Fig. 20 (*b*)), it will probably be necessary to move the coil up and down to obtain an indication on test, and when doing so care should be exercised not to force the coil against the pole face. Perhaps the best method is to make the test with the coil supplied from a receiver which, in the case of mains-energised speakers, is not connected to the mains *in any way*. As a rule, leakage from a moving-coil winding to the pot is due to bad centering—too little clearance between coil and pot—coil having assumed an oval shape, or coil tilted, due to bias from diaphragm which is not concentric. Having traced the cause, the remedies are obvious in these cases.

A Special Case

In Fig. 21 we have a diagrammatic representation of a high resistance choke-fed, moving-coil loud speaker whose electro-magnet is fed from D.C. mains supply. Should a leak occur between the energising winding and pot and between the moving coil and pot, a large current will flow through the moving coil, possibly burning it out, and certainly giving it a wild inclination to leap out of the pot. This effect was observed by Dr. N. W. MacLachlan and described by him in the *Wireless World* some time ago. Attention is again drawn to it here for the benefit of readers who may be employing speakers of this type.

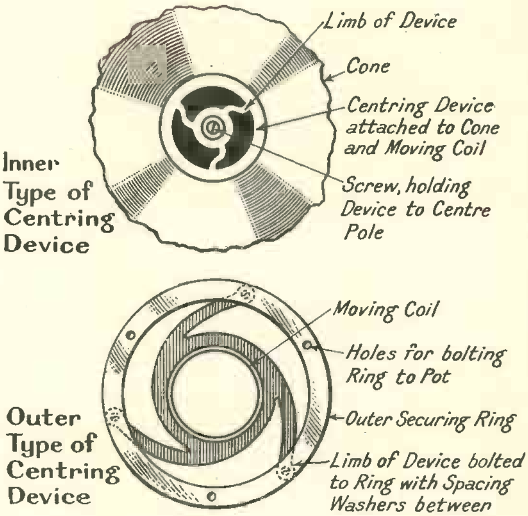


Fig. 22.—Two Types of Centering Devices.

Centering Devices

Though of many various shapes and forms, these can usually be classed under two main heads, the "inner" and the "outer" type. The "inner" is usually secured to the centre pole, whilst the "outer" is secured to a ring, which is in turn secured to the outer face of the magnet (Fig. 22). Various noisy troubles are directly traceable to the centering device.

In the case of the "inner" type, the screw which secures it to the centre pole may have worked loose, causing "dithering"—a similar effect will occur with the "outer" type should the bolts which secure it to its ring become loose. Occasionally it so happens that the device has become loosened from the coil or cone. Le Pages liquid glue, Rawlplug Durofix, or, better still, bakelite cement, may be used for refixing purposes. In all cases the instrument should be left until the fixing solution is thoroughly set before being put into use again.

Broken or Damaged Limbs of Centering Device

According to the nature and position of the break, so either "chattering," "dithering" or "flapping" noises will be produced. A repair may sometimes be effected by fitting an attachment over the existing device, but it is much better to remove the faulty device and replace it by a new one of the same pattern if it is desired that the speaker shall function as before.

Warped or Bent Limbs of Centering Device

This will tend to throw a biasing force on the driving unit, with the result that the drive will operate as in Fig. 17. The limbs should, if possible, be bent back again or re-straightened. If the trouble persists a new centering device will be found to be the only remedy.

Short-circuited Turns in Windings Carrying Speech Currents

This trouble is not easy to trace without fairly elaborate apparatus. One certain

Fig. 23.—Lifting Out the Diaphragm and Coil of a Magnavox Speaker.
This will enable the speech coil to be examined if short circuited or broken windings are suspected.

result of short-circuited turns is that a loss will occur. This may take place over the whole range of frequencies, or on only the high or low frequencies. Having ascertained that the loss is not in the receiver or amplifier, and that a loss *is* occurring—compared with previous results—it may be safely assumed that the windings are at fault. If a high-resistance speaker, in the speech coil; if a low-resistance speaker, probably in the transformer. The only remedy is to fit new windings in place of the offending ones, and again the makers can most suitably deal with this.

Clamping Ring not Secure to Chassis

In all types of cone loud speaker it is essential that the suspension or surround be firmly secured, and if the clamping ring is not securely screwed or bolted to the chassis, " rattling " and other troubles will ensue (Fig. 18). Similar troubles will ensue with horn-type loud speakers should the horn not be securely fitted to the unit. Further, the washers between which the diaphragm is clamped, in the case of a horn speaker, may well be compared to the clamping ring and chassis of the cone type.

Faults in Electrostatic Loud Speakers

In these loud speakers insulation is of paramount importance and, bearing in mind that these speakers are similar to a condenser, and that to be sensitive the construction must, of necessity, be to an extent delicate, it is recommended that all but the most simple of repairs be entrusted to the makers. The same remarks will apply to others of the " various " class, such as the Johnson Rahbek and " Audalion."

In conclusion, it is desired to add that the faults dealt with in the foregoing pages are such as are frequently met with, and it is not proposed in this article to deal with faults due to design, etc., a subject which, to say the least, is rather controversial.

SERVICING

THE BURGOYNE POPULAR THREE, 5-VALVE PORTABLE, SILVER SEVEN, OLYMPIC THREE AND DREADNAUGHT MODELS

THE POPULAR THREE

THIS is a three-valve battery operated receiver, with a built-in frame aerial and speaker completely self-contained. A leaky grid detector is followed by two transformer-coupled stages to output power valve. Single dial control is obtained by the volume control being incorporated with tuning control. Provision is made for outside aerial and earth if required.

Fig. 1.—THE FIRST STAGE IN DISMANTLING THE BURGOYNE SILVER SEVEN RECEIVER.
This consists of removing the control knobs as shown.

Selectivity

The lack of selectivity which too often mars reception with sets employing a detector and two low-frequency stages is not evident with this receiver; on the contrary the directional properties of the frame aerial, combined with the ease of critical reaction control, gives adequate selectivity for all normal requirements. Looking over the circuit there will not be found any unusual feature, as the arrangement follows standard and reliable practice. The first valve is a cumulative grid detector, which is followed by two L.F. transformer-coupled stages.

Quality

The output valve, a Cossor P215, working at about 90 volts high tension, feeds directly into a specially matched speaker unit. A small bypass condenser is made good use of in the anode circuit of this last valve and provides the necessary balance of tone. As a result, the quality obtained is characterised by a clarity and crispness not always found in portable or transportable receivers.

Selection of Voltages

There are no de-coupling devices used in the set, a separate high-tension feed being available for each of the three-valve anode circuits. A wide selection of voltages is thus obtainable for each individual valve, which would otherwise be impossible to achieve if a common high-tension supply lead used in conjunction with de-coupling resistances were utilised.

This ability to vary individual plate

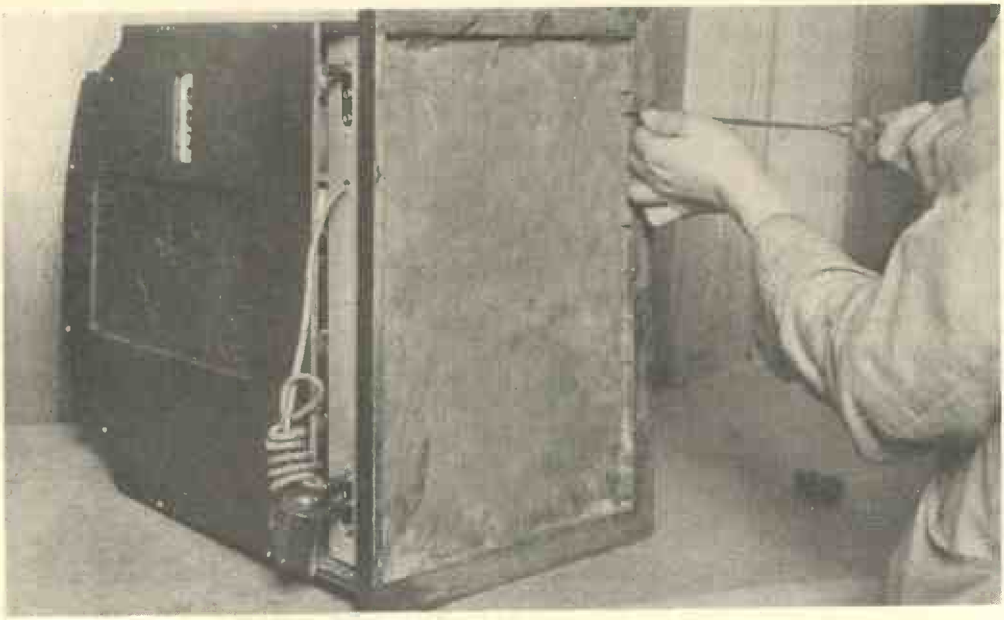


Fig. 2.—THE SECOND OPERATION.

Removing the three screws from the base of the cabinet.

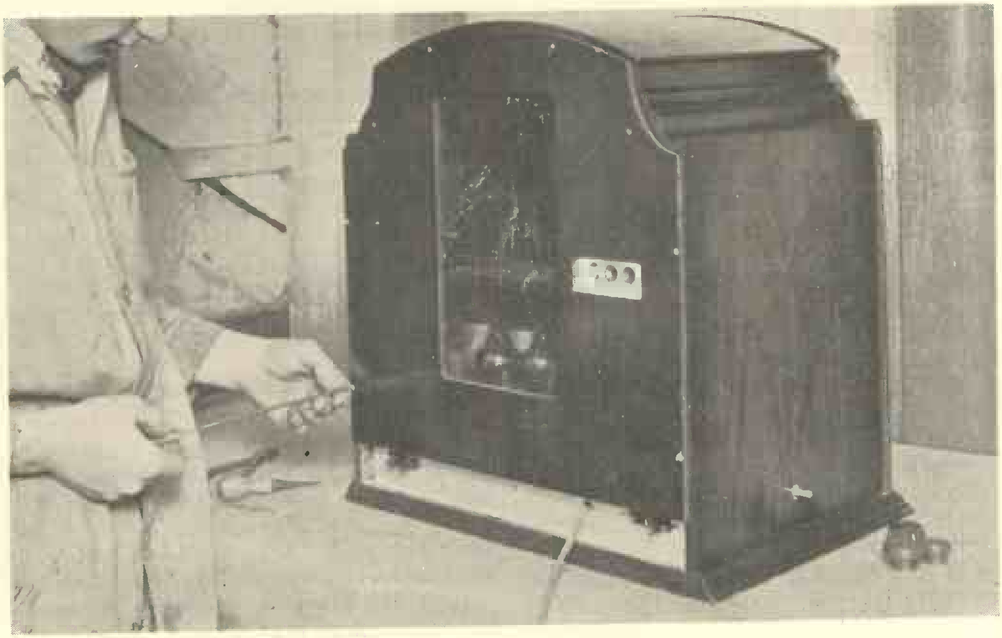


Fig. 3.—THE THIRD OPERATION.

Showing how the back of the cabinet can easily be removed. The next operation is shown in Fig. 5.

voltage is a distinct advantage, as the life of the battery is increased thereby. As the potential decreases, when the battery has been in use some time, the H.T. plugs can be moved to points giving a relatively higher voltage.

Operating Notes

The back of the cabinet should first be removed and all battery plugs should be firmly fixed in their correct sockets. It would be as well to mention here the exact sockets to use. The high-tension negative is easily discernible by the flexible lead bearing the small label HT–, GB–1 and GB–2 plugs should be placed in the battery sockets marked –3 and –6 volts respectively. The types of valves should be strictly adhered to, and a great saving of high-tension current is effected by using the correct amount of bias voltage. HT + 1; HT + 2 and HT + 3 should occupy sockets 63, 81 and 90 respectively, although slight variations can be tried.

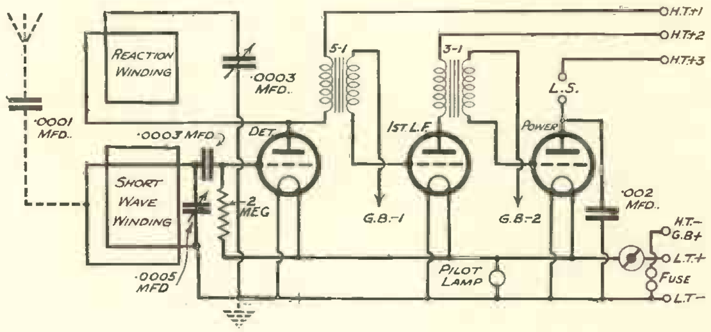


Fig. 4.—THEORETICAL CIRCUIT DIAGRAM OF THE BURGOYNE POPULAR THREE RECEIVER.

The Accumulator

It should be noted that the Exide glass cell only requires the addition of acid to put it in full working condition. It remains only to tighten the red and black spades to the corresponding red and black terminals on the accumulator before replacing the back and reverting to the tuning controls. The small switch directly beneath the tuning dial should be moved to the "On" position. The dial scale will now be illuminated, and is an indication that the receiver is "alive."

Tuning

To tune in any station turn the volume control knob in a clockwise direction until a soft "plop" is heard in the speaker. The set is now in its most sensitive state for receiving signals. Rotate the tuning "Selector" dial until a carrier wave denoted by a whistle is heard, then turn the volume knob slowly back in an anti-clockwise direction till the whistle resolves into speech or music. A slight re-adjustment of the tuning dial will be all that is necessary to obtain maximum signal strength. For local reception the volume control can be left fully to the left and the station tuned in by aid of the "Selector" dial only.

Faults that May Occur

With regard to the faults likely to develop they are, fortunately, very few.

Crackling Noises

Crackling noises in the receiver are due to many causes. First of all, loose wires should be looked for and all flex leads should be carefully examined for broken strands. If any are found on the plug ends refix the plug, and if on the receiver end the leads should be re-soldered into position. See that the fuse bulb and the pilot lamp are screwed firmly into their holders. Push the valves securely into their sockets.

Make Sure the H.T. Battery is not Faulty

Should the crackling still persist the high-tension battery should be suspected, and a change should be tried, which will generally put matters right.

Complete Cessation of Signals

Complete cessation of signals may possibly occur; and if the fuse is found to be intact it is as well to have the valves themselves tested.

Short Circuits

Should the fuse momentarily give a bright flash a short circuit in the high tension circuit is indicated and the set should immediately be switched off and the H.T. plugs removed from the battery. A fault of this description spells complete ruination of the battery unless the trouble is located at once.

METER TESTS

The most accurate and reliable method of testing is, of course, by the use of a sensitive meter that consumes but very little energy, for the purpose of measuring either the current passing in the circuit or the voltage applied.

Probably the most useful range of a testing milliammeter is that with readings up to 10 or 12 milliamperes, for this will cover nearly all of the most popular types of sets available.

A good reliable voltmeter with two ranges, the lower up to 10 volts and the higher giving a reading up to a maximum of 150 volts should also be available having a sensitivity of about 1,000 ohms per volt.

The most useful points for testing in the circuits are as follows :—

How to Use the Milliammeter

By removal of the plug attached to the fuse holder the milliammeter can be inserted between this point and the socket from which it has been removed, which indication gives the total current consumption of the receiver. The value when the proper high tension voltage and grid bias is applied should be in the neighbourhood of 5 to 6 milliamperes. The positive terminal of the meter should be connected to the released wander plug and the negative connected to the H.T. minus socket in the battery.

The current flowing in the first low-frequency anode circuit can be similarly checked by replacing the fuse-holder or wander plug into H.T. — socket and removing H.T. plus 2 wander plug. Insert the milliammeter between the plug just removed and the socket from which it was removed, connecting the socket on the H.T. battery to the positive terminal of the meter. Likewise the detector anode current may be checked by inserting the meter between the wander plug marked H.T. plus 1 and the appropriate high-tension socket.

The correct condition of the power valve anode current only may be checked by removing the loud speaker lead from the anode terminal of the power valve and inserting the milliammeter between these two points, which should read about 3 to 4 milliamperes.

How to Use the Voltmeter

The correct high-tension voltages can be ascertained by taking the voltmeter and setting it to the highest range. This should be somewhere in the neighbourhood of either 120 or 150 volts. The negative terminal of the meter should be attached to some point on the negative side of the filaments, or, if more convenient, to the negative terminal of the low - tension accumulator. The positive terminal of the meter should now be connected to a wandering lead and connection made to the points of the circuit which it is desired to check, namely, the anode connection on the first valve holder or detector valve, the anode connection on the second valve holder or low-frequency valve, and again on the anode connection of the power valve. These three readings should be 63, 81 and 90 volts respectively. No reading on any one circuit will indicate a break, and the particular circuit should be followed through until fault is located.

After having checked these figures and found them to be correct, the lower range of the voltmeter may now be utilised, which should not exceed 10 volts.

In turn, the 2-volt accumulator and grid bias battery should be checked, the former being read whilst the set is switched on, or, in other words, whilst the accumulator is under load. The load readings will give a far better indication of the condition of the accumulator than any other method.

The grid-bias battery voltage may be checked by connecting the positive terminal of the meter to the negative terminal of the low-tension accumulator, and the wandering lead from the negative side of the meter in question to the G.B. plus 1 and G.B. minus 2 plugs respectively, noting that the voltages are in accordance with the following figures :—

Fig. 5.—The Fourth Operation.
Removing the three screws from chassis inside the cabinet.

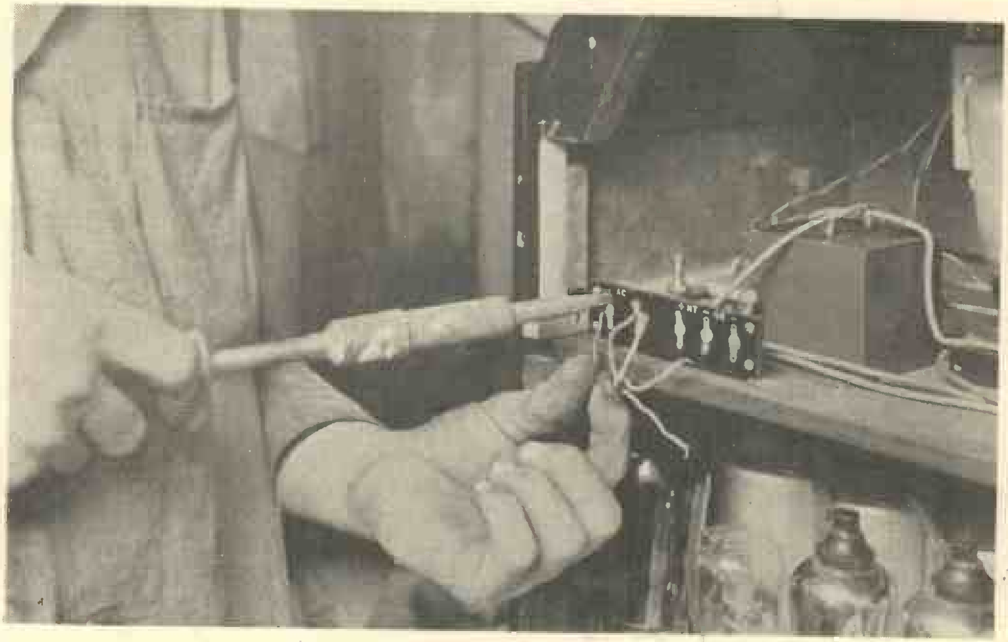
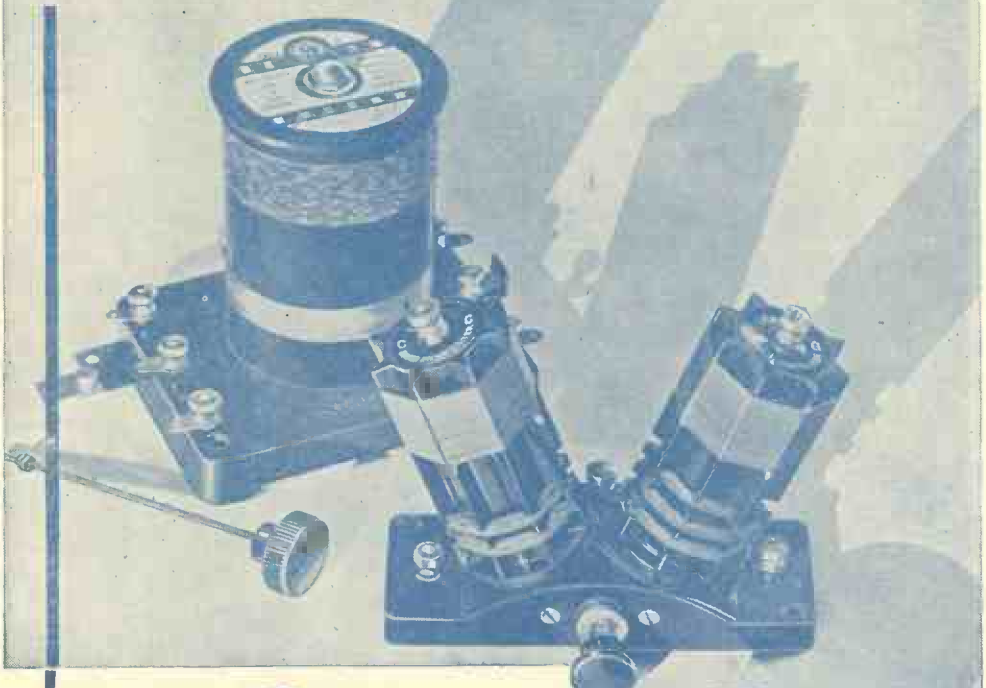


Fig. 6.—The Fifth Operation.
Unsoldering the leads from the output board.

PERFECT RECEPTION
demands



Lewcos
RECD

RADIO COMPONENTS

The pioneering work undertaken by "Lewcos" in the early days of wireless enables this world-famous firm to produce components of the highest quality. Thousands of Constructors depend upon them for first-class reception and reproduction.

Stocked by all reputable dealers.

Please quote these Reference Numbers when Applying for Leaflets:—

COMPONENTS OF EVERY DESCRIPTION

L.F. and H.F. Transformers	*Ref. Nos. N76.*
L.F. and H.F. Chokes	,, ,, *N76 & 78.*
Potentiometers	,, ,, *N79 & 81.*
Band Pass Filters	,, ,, *N73a.*
Spaghetti Resistances	,, ,, *N78.*
Glazite Connecting Wire. Silk and Covered Wires.	

LEWCOS RADIO PRODUCTS FOR BETTER RECEPTION

THE LONDON ELECTRIC WIRE COMPANY AND SMITHS LIMITED, CHURCH ROAD, LEYTON, LONDON, E.10.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

THE SUPER-HETERODYNE

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

VARIABLE CONDENSERS

SERVICING BURGOYNE RECEIVERS

1/-

Part 11

IN ABOUT 24 WEEKLY PARTS

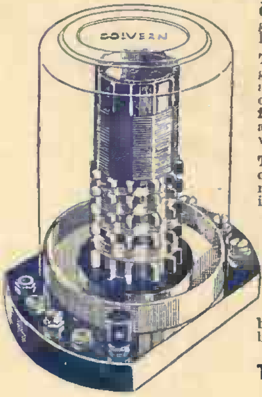

COLVERN

Fig. 7.—The Sixth Operation.
Removing the screws which hold the power pack to the baseboard.

Valve.	Make.	Type.		Lead.	Approx. Voltage.	Approx. Milliamps.
Detector	Cossor	HF210	Metallised	H.T.+1	63	1·0
L.F.	,,	LF210	,,	H.T.+2	81	1·4
Power	,,	P215		H.T.+3	90	3·0
				G.B.−1	−3	
				G.B.−2	−6	
	Total consumption					5 to 6

Battery Replacements

H.T. Battery—

Exide Drydex H.1025 { H.T. 90 volts / G.B. 9 ,, } 1 unit

L.T. Accumulator—

Exide D.T.G. 2 volts

THE 5-VALVE PORTABLE RECEIVER

The Burgoyne 5-valve portable receiver utilises a circuit of the straight type which is practically reduced to its simplest proportions. Aperiodic choke coupling is used for the two high-frequency valves, which are followed by a cumulative grid detector and two low-frequency transformer coupled stages. The latter arrangement is divided into two sections, the transformer following the detector valve having a ratio of 1–5, while the transformer which feeds the power valve has a lower ratio of 1–3.

The Frame Aerial

The pick-up medium of the instrument is a frame aerial wound on a framework which houses the loud speaker and can be removed *en masse* from the lid of the cabinet for inspection if required by removal of screws in each of the four corners. The windings are divided into two portions, the long wave section being made up of 51 turns (with Bakelite tuning condenser or 35 turns with air-spaced tuning condenser) of No. 30 gauge double cotton-covered copper wire, the short wave section having an additional winding of 17 turns of gauge 24 double cotton-covered copper wire. Both of these windings are wound in the same direction. Reaction is obtained by tapping the fourth turn from the outer end of the short wave winding.

Loud Speaker

The loud speaker itself is of the cone type using a specially matched reed unit.

In the case of replacement being required of the latter unit, it is advisable to return it to the makers for correct fitting.

Fault Finding

Fault finding on this receiver will be found to be extremely easy if the following sequence of tests is carried out :—

Test No. 1.—The Fuse Bulb and Accumulator

If no signals are obtainable when the on-off switch is operated in either wavelength position, the first thing that should be done is to check whether the fuse bulb has blown as a result of a faulty contact. Remove the H.T.— wander plug and touch with the plug end the minus terminal of the low-tension accumulator. In this position the connections of the fuse bulb are inserted across the two-volt accumulator, and, providing the fuse is intact and correctly screwed home, the latter should glow to some appreciable extent. If it fails to do so, either the fuse bulb is blown or there is no charge in the accumulator. This last condition can be further checked by replacing the high-tension minus lead back to the high-tension minus socket of the battery and removing the spade terminal from the positive terminal of the accumulator, and touch the $1\frac{1}{2}$ volts socket of the grid-bias section of the high-tension battery. If the bulb now glows it is obvious that there is no charge in the accumulator and this should be replaced or re-charged as necessary.

If, however, there is still no glow from the particular fuse bulb inserted, providing that the bulb itself is screwed well home in the holder, it can safely be assumed that a replacement of this item is necessary.

Fig. 8.—THE FINAL OPERATION IN DISMANTLING THE SILVER SEVEN RECEIVER.

Disconnecting the mains supply from the power pack. The power pack can now be withdrawn, as shown in Fig. 10.

Test No. 2.—Loud Speaker Test

Providing the power valve is in working order and the grid-bias plug is inserted in the correct socket, on removal of the high-tension battery plug marked H.T. + 3 a loud click should be heard from the speaker unit. If this indication is absent a further test for continuity of the unit may be carried out by means of a small test battery and a pair of headphones connected in series, one side of the headphones being connected to one side of the battery, and the remaining battery terminal and headphone terminal utilised to test the continuity of the windings as follows :—

Remove the high-tension battery wander plug marked H.T. + 3 and remove the power valve from its socket. Take a connection from the small test battery terminal and place it in contact with the plate socket of the power valve holder. The other headphone connection should be made to make contact with the H.T. + 3 plug, when a decided click should be audible in the phones on either making or breaking the circuit. If this test fails to give the required indication, it can be safely assumed that the unit is at fault, and it is suggested that the instrument should be returned to the makers for replacement of this item, as previously mentioned.

Test No. 3.—High-Tension Supply Localisation

Test the voltage of the high-tension battery with, if possible, a high-resistance voltmeter and note that the full load-voltage obtainable should not be less than 90 per cent. of the voltage specified for that particular make of battery. A better indication of the condition of this unit is obtained by taking the voltage readings first with the set switched off and then with the set switched on. The difference between the two readings obtained should not vary more than about 2 or 3 volts.

Faults in the Anode Circuits

If the above tests fail to disclose any fault, attention should now be given to the valves with the instrument switch on. Remove one valve at a time, starting from the left-hand side at the first high-frequency valve, and working to the right as far as the power valve.

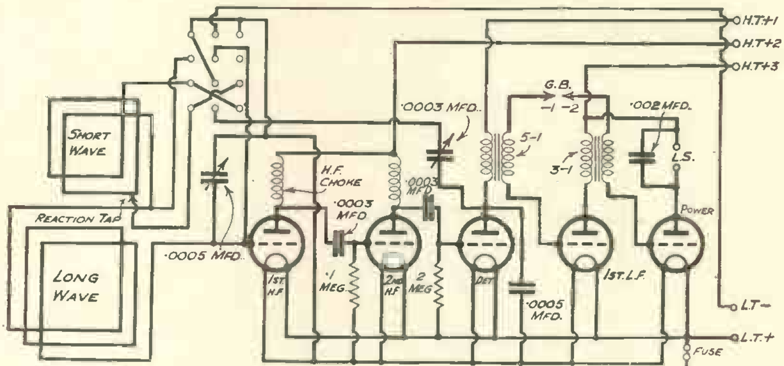


Fig. 9.—Theoretical Circuit Diagram of the Burgoyne 5-Valve Portable Receiver.

As each valve is removed a loud click should be heard in the speaker, denoting that a certain amount of anode current is flowing in that particular circuit, providing the respective high tension voltages are connected. If no decided click is heard a disconnection in the anode circuit of that particular valve should be suspected, or the valve itself may have lost its emissive properties. The latter fault can be checked and eliminated by inserting another valve known to be in good condition. In the case where still no signals are audible the simplest manner in which an open anode in circuit can be overcome in the case of either the first or second high-frequency stages is to change the H.F. choke. As far as the detector and first low-frequency valves are concerned, the transformers should be checked for continuity and repaired or replaced as necessary.

Test No. 4.—Frame Testing

A small test battery and a pair of headphones (or a fuse bulb holder and lamp) should be connected in series as previously outlined for locating faults in the loud speaker. Taking a flexible lead from the free side of the test battery, and another from the free end of the headphones or fuse bulb holder respectively, place one of them in the first brass socket in the left-hand bottom corner of the loud speaker fret, making a connection with the other lead in either the second and third sockets of the same set and the socket in the bottom right hand corner. In any of these positions continuity of the circuit should be evident by a loud click in the headphones or a light in the fuse bulb. If these indications are absent, remove the four screws holding the fret in place in the lid of the instrument and examine the frame aerial windings for a disconnection.

Examine the Valve Legs

It is advisable periodically to examine the valve legs and see that they make good contact in their respective sockets; if necessary, slightly open them with the small blade of a penknife. Dirty valve legs and bad-fitting valves give rise to objectionable noises.

Operating Notes

Valves fitted as standard are as follows:—

1st H.F.	Mullard	PM1HF.
2nd H.F	,,	PM1HF
Detector	,,	PM1LF
1st L.F	,,	PM1LF
Power	,,	PM2

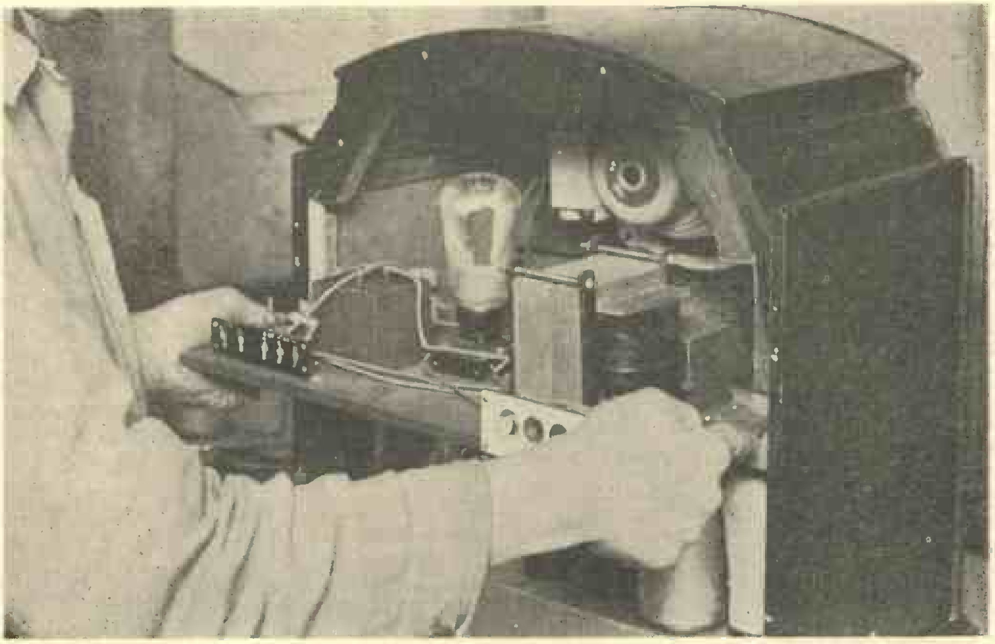


Fig. 10.—Withdrawing the Power Pack from the Cabinet of the Burgoyne Silver Seven Receiver.

On the extreme right can be seen the fuse board, behind which is the mains transformer with smoothing condenser block following. Above the transformer is the moving coil speaker, the field coil of which is used as a smoothing choke.

Fig. 11.—Withdrawing the Receiver Chassis.

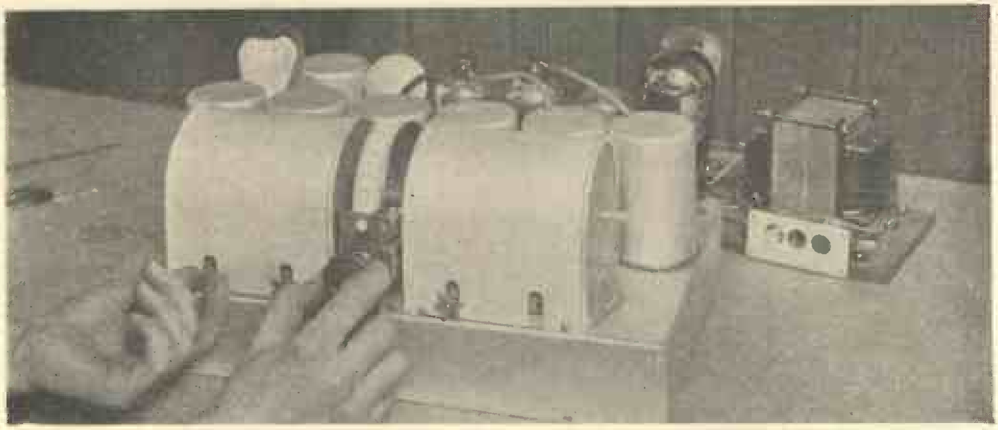


Fig. 12.—This Shows how Access can Easily be Obtained when Adjusting the Tuning Condensers.

From left to right the four sections are as follows :—First section, tuning the first screened coil connected to grid circuit of first S.G. valve ; second section, tuning the secondary of second screened coil ; third section, tuning the third screened coil ; and fourth section, tuning the fourth screened coil.

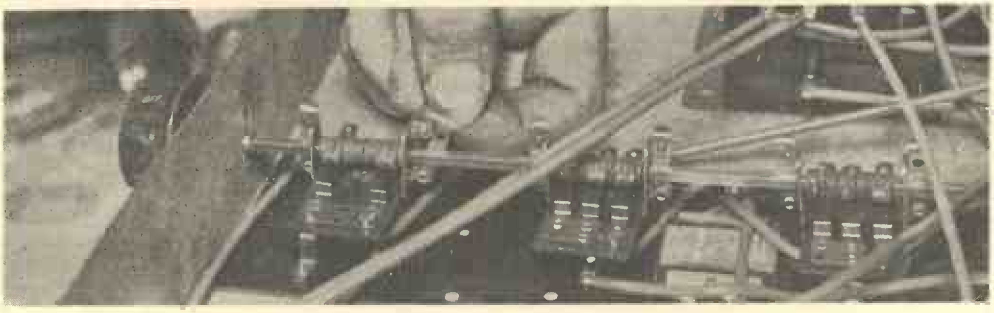


Fig. 13.—Unclipping the Switch Platform.

The switch spindle for the four ganged coils is retained in position by five pairs of flat steel clips.

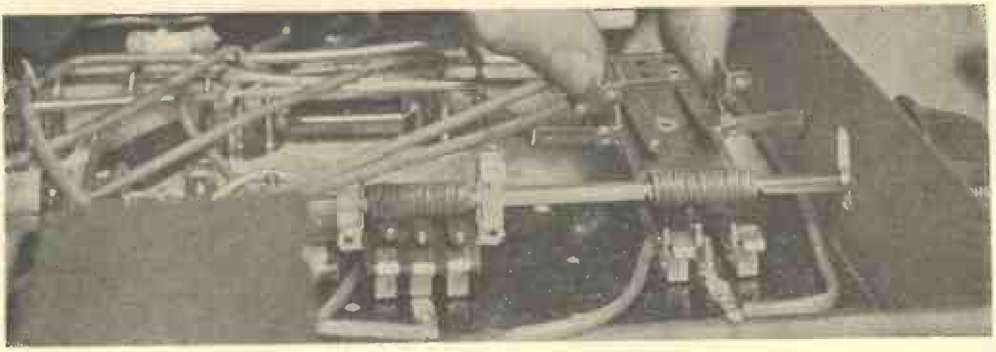


Fig. 14.—Method of Removing the Switch Platform.

The first screened coil switch platform is here being removed from the ganged switch spindle and coil clips.

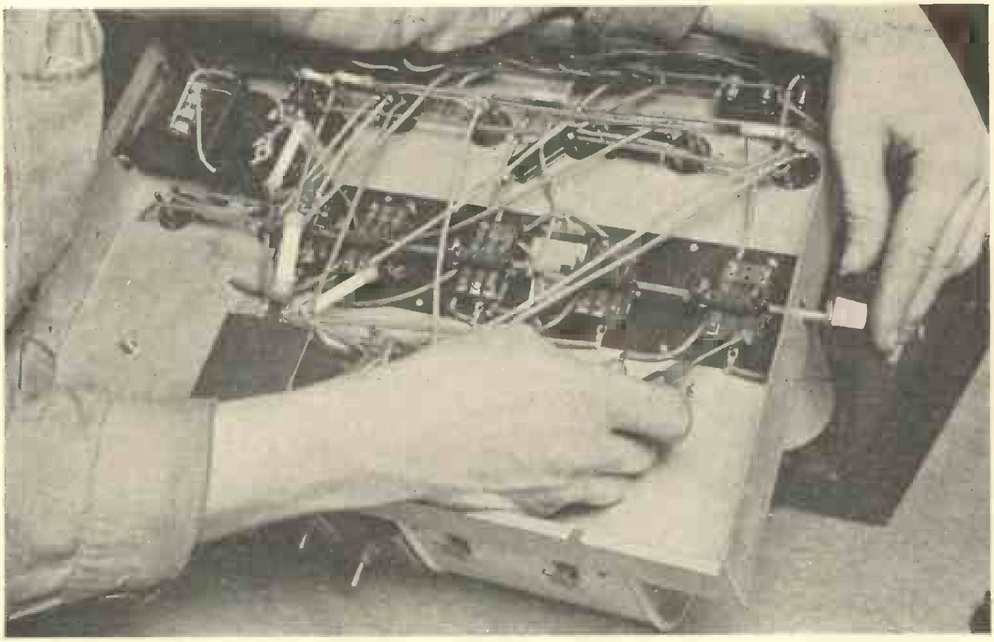


Fig. 15.—Testing the Contacts on the Wave-change Switch.

This shows the ganged coil switch spindle, platforms and panel complete. Phosphor bronze contact fingers are used, tipped with silver contact points. Fibre cams operate upon the fingers to make a sliding, self-cleaning contact, but on removal of the pressure supplied by the cam, care must be taken to see that they really lift off the nickel silver contact strips situated immediately below the contact points. In the absence of the latter feature they should be sprung outward a little more with the end of a small screwdriver to ensure that they really break the circuit when required.

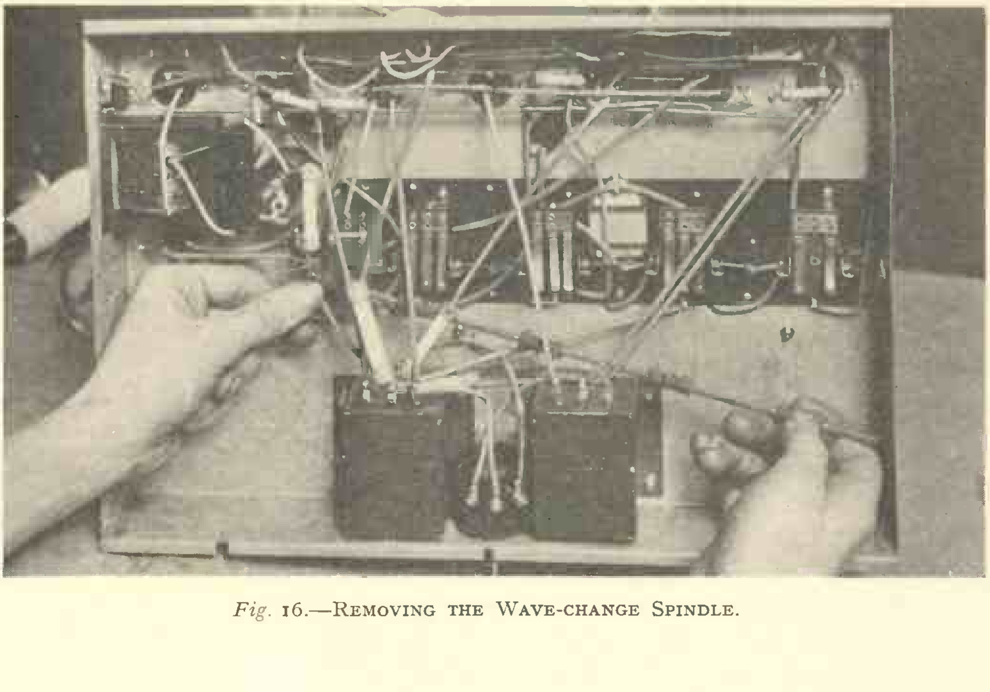


Fig. 16.—Removing the Wave-change Spindle.

Fig. 17.—FITTING NEW FUSE BULB TO CORRECT TAPPING FOR MAINS SUPPLY.

Voltage Tappings on H.T. Battery

H.T. + 1	27–36 volts.
H.T. + 2	36–45 ,,
H.T. + 3	90 ,,
G.B. − 1	4½ ,,
G.B. − 2	9 ,,

H.T. Battery replacements—

Exide Drydex	Type H.1025	90 volts	1 unit
	G.B.	9 ,,	

L.T. Accumulator replacements—

Exide	Type FWJ7	2 volts

THE SILVER SEVEN

The Burgoyne Silver Seven is a receiver of the well-known supersonic heterodyne type, now rapidly coming into prominence and public favour owing to the insistent demand for an instrument capable of giving trouble-free and interference-free entertainment of the highest quality. The conditions prevailing on the broadcast frequencies as used in Europe at the present time demand a very high standard of performance so far as selectivity is concerned, apart from the fact that a general rise in appreciation of good quality reproduction is evident everywhere. The early type of supersonic heterodyne suffered in many ways from defects which to-day cannot be tolerated, and in the Burgoyne edition of the instrument making use of the supersonic principle of reception, it can be safely asserted that the highest standard of present-day technique has been embodied in its entirety to produce a receiver capable of providing a lengthy list of programmes at almost any hour of

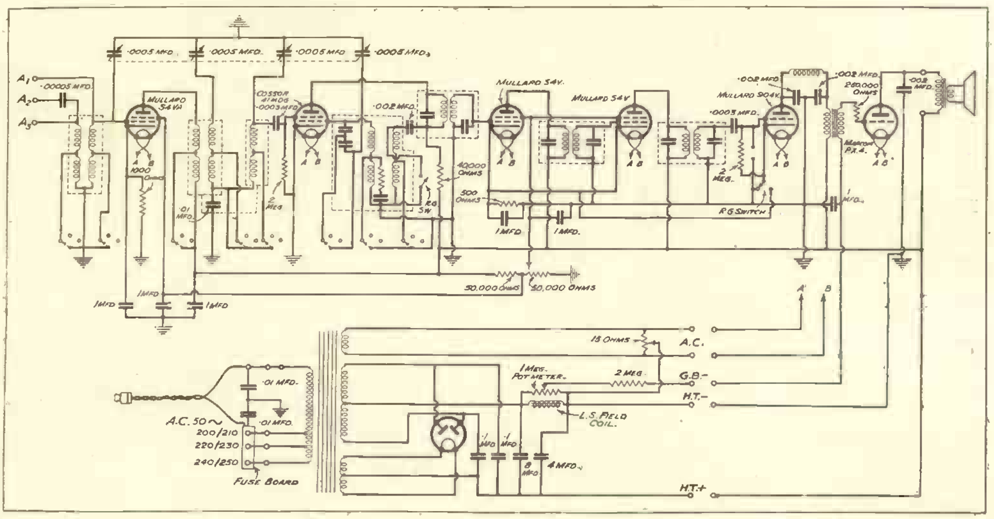


Fig. 18.—THEORETICAL CIRCUIT DIAGRAM OF BURGOYNE SILVER SEVEN RECEIVER.

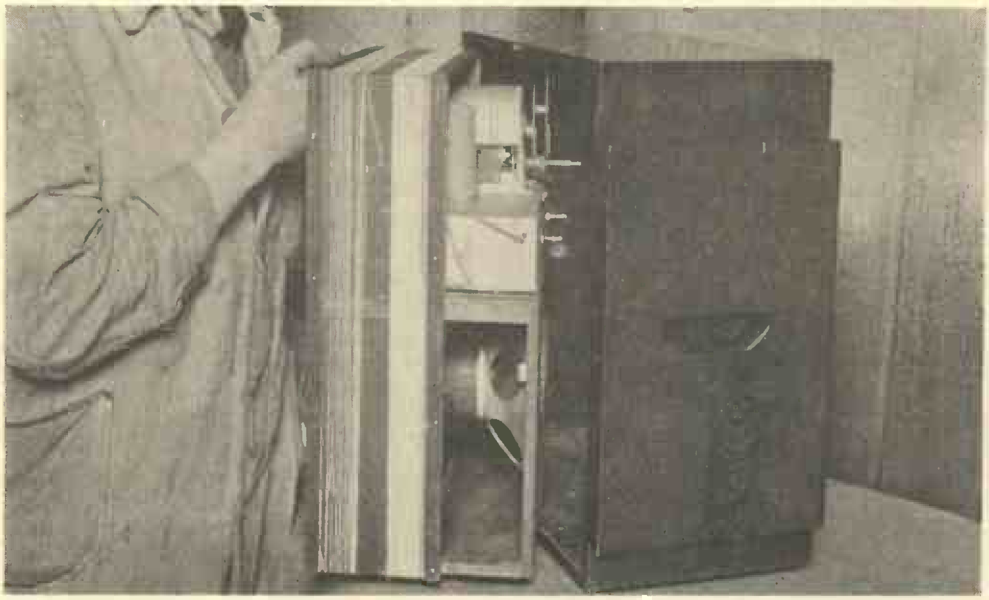


Fig. 19.—METHOD OF REMOVING COMPLETE CHASSIS AND FRAME FROM THE CABINET OF THE BURGOYNE DREADNAUGHT RECEIVER.

Showing the internal frame aerial and chassis being removed after the retaining screws are withdrawn from the sides of the interior. The medium and long wave windings are clearly seen, together with the moving coil loud speaker in the lower compartment, and the receiver chassis on the uppermost side of the shelf.

the day or night providing transmissions are in progress.

Circuit Arrangement

The circuit arrangement comprises an inductively-coupled aerial transformer forming a pre-detector fundamental high-frequency amplifier feeding a tuned capacity coupled band-pass filter. This arrangement is sought in order to provide a well-balanced overall amplification of the band of frequencies for which the instrument is designed, the inductive coupling of the aerial transformer favouring the higher frequencies and the capacity coupling of the detector band filter favouring the lower range.

Double Grid Valve

What perhaps may be an innovation in the instrument is the use of a valve having two grids, normally termed a double grid valve, or its Continental equivalent, Bi-grid valve. This must not be confused with a standard screen grid valve, as the latter has normally a positive potential applied to the screening grid. In the double grid type, however, the additional grid performs almost the same function as the primary grid, but fed only with high-frequency oscillations, from a different tuned circuit to that which is oscillating at the fundamental frequency being received. This valve therefore is undoubtedly an ideal type, for we can detect the incoming signals on the one grid and provide an artificial oscillating potential on the other, the two frequencies intermixing and producing the required frequency for the intermediate high-frequency amplifying stages which follow.

The Screen Grid Amplifiers

The third and fourth valves are standard screen grid high-frequency amplifiers working on a fixed frequency of 126 kilocycles, the overall amplification of a distortionless character being controlled by the variation of the screen grid potential of the two valves in question.

A cumulative grid detector follows with a high ratio step-up low-frequency transformer providing good quality and sufficient sensitivity to load up a power valve of the PX4 class.

Power Supply

The power supply is a standard valve rectifier of the class two type, rated to supply 380 volts, at a consumption of 60 milliamps. The exceptionally smooth supply of current for the needs of the set is obtained by utilising the field coil of the moving coil loud speaker also acting as a smoothing choke.

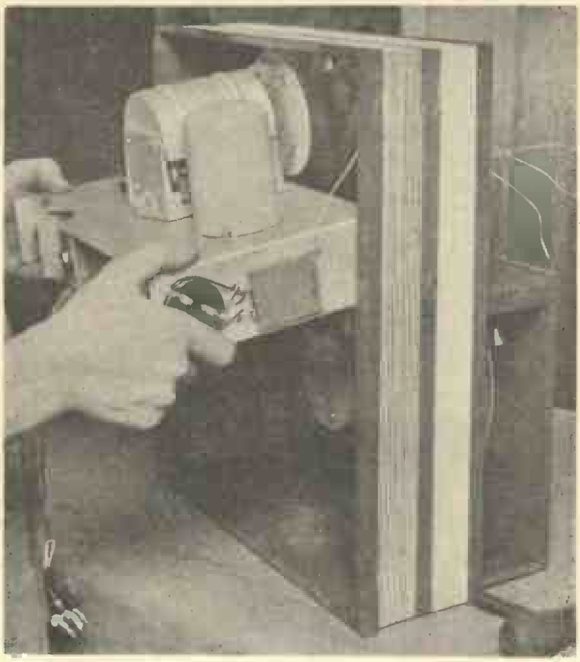


Fig. 20.—Withdrawing the Chassis from the Frame after Disconnecting the Frame Aerial Leads and Loud Speaker Connections.

The Fuse-Board

Provision is made for the protection of the set, and the appropriate connection of the mains voltage, by means of a fuse-board exposed half-way up the back of the cabinet. The fuse-board referred to is arranged with three sockets, which are marked 200/210, 220/230 and 240/250 volts respectively.

Connecting Set to Appropriate Mains Supply

All that is necessary to connect the set to the appropriate mains is the insertion of the 4 volts 500 milliamperes fuse bulb supplied. The voltage of the mains should in the first place be ascertained in the particular locality to which it is intended that the set be connected. If this information is not available, immediate recourse may be had to the information given on the meter, or, of course, it will be gladly given on request to the nearest local supply authority.

It should be emphasised that it is necessary to insert only a bulb of the correct consumption, namely 4 volts, 500 milliamperes. It is incorrect to insert a bulb of the usual flash-lamp type, as this will be found to give very unsatisfactory results, due to the fact that the normal ratings of this component are in the neighbourhood of 120 to 150 milliamperes.

The Pilot Lamp

The pilot lamp illuminating the tuning dial is also of the same type, and it can be readily perceived that both these items are interchangeable. Should it become necessary, as a matter of great urgency, the pilot lamp bulb can be used for a fuse, but it is necessary to remove the back cover before it can be reached.

The Valves

Further, with regard to this instrument, a large number of tests have been conducted as to the suitability of the valves as stated, and it must be borne in mind that valves other than those fitted in the respective positions must be looked upon with disfavour, for their characteristics may be entirely different from those required. In this connection, therefore, the manufacturer cannot accept responsibility for results on the instrument using valves other than those specified, but should the listener or service man have doubts on any point he is strongly advised to communicate with the manufacturer at the earliest possible opportunity. Technical information will be given freely and gladly to assist all users.

Faults that May Occur

The main faults that are likely to occur are failure of the fuse or bad contacts in the valve pins. The former should be withdrawn and checked by means of a 2- or 4-volt battery, while the manner of overcoming the latter should be obvious. Defective valves should next be looked for by the simple process of elimination by substitution, not forgetting that the rectifying valve also comes under this classification. If they are in order, feel by the touch of the fingers whether the mains transformer is running cool; the temperature should not exceed that which can be comfortably borne.

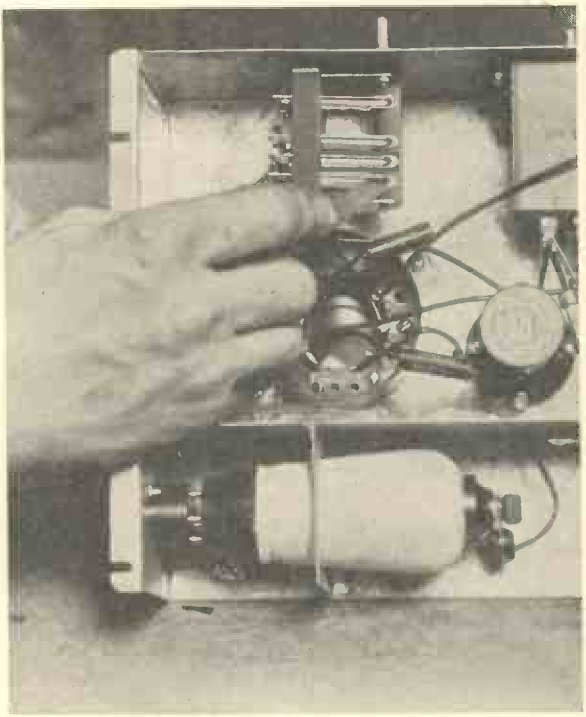


Fig. 21.—CLEANING THE CONTACTS ON THE WAVE-CHANGE SWITCH OF THE DREADNAUGHT THREE RECEIVER.

This is done with emery paper, as shown.

Examine Exposed Leads

All exposed leads should be examined for broken or frayed connections and replaced where necessary, but should there be any doubts about the matter the instrument should be returned to the makers.

Dial Light

A burnt-out dial light should not be allowed to remain, as the device forms a positive indication that the set is on, a fact which may not be noticeable with the volume control in the minimum position. Beyond such small matters as loose knobs on their respective spindles, and bad or loose contacts in the aerial, earth and radiogram plugs and sockets, there is very little else that can go wrong in a manner that can be handled by the service man.

Operating Notes

A few words on the socket connections at the back of the instrument may be summarised as follows:—

Terminal A.1 is for use with a very short aerial connection, and excellent reception can usually be had from most of the more important European transmitters on a 3-foot length of wire.

Terminal A.2 is for use with medium class aerials, such as the ordinary indoor type or a small or inefficient outdoor type. Good all-round reception should be possible under these conditions, but it must be remembered that it is possible to overload the set severely by injudicious manipulation of the volume control, which should not be turned on more than is necessary for the volume required.

Terminal A.3 is for use with all good aerials of either the indoor or outdoor types, particularly so when the receiver is located but a few miles from a powerful broadcasting station. The volume-control knob should prove very effective in handling the local transmitter.

Plugs and sockets are provided for attachment to a pick-up or pick-up volume control.

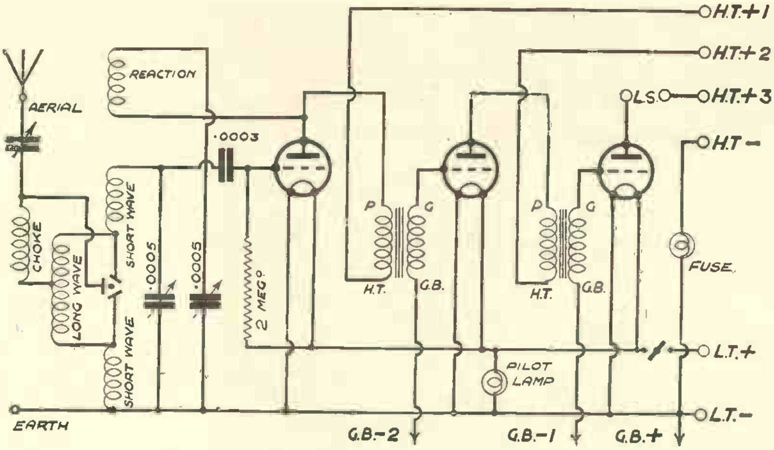


Fig. 22.—Theoretical Circuit Diagram of the Burgoyne Olympic Three Receiver.

Valves fitted as standard are as follows :—

1st H.F.	Mullard	S4VA	Metallised.
1st Detector	Cossor	41MDG	,,
1st I.F.	Mullard	S4V	,,
2nd I.F.	,,	,,	,,
2nd Detector	,,	904V	,,
Power	Osram	PX4	
Rectifier	Mazda	UU 120/350	

Fuse Bulb 4 volt 500M/A.
Pilot Bulb 4 volt 500 M/A.

The two latter are interchangeable.

THE OLYMPIC THREE

A modern three-valve receiver requiring an outside aerial and earth, and capable of receiving British and Continental stations. The set is entirely self-contained.

Although it is generally supposed that one stage of screened-grid amplification is necessary to obtain selectivity in the London areas, a surprising degree of this much-sought quality has been achieved by the inclusion of a specially designed tuning coil preceding a leaky grid detector and two low-frequency stages.

The Long Wave Section

A glance at the circuit diagram will help to confirm this statement, and also make apparent, to those with some technical knowledge of radio, that the long-wave section of the coil has received considerable attention.

As a result, the swamping of the lower part of the long-wave section has been entirely eliminated, thus getting rid of a common source of interference, which, up till quite recently, was thought to be unavoidable in sets of this description.

The combined efficiency of components and modern valves have made it possible to place a straight-three receiver before the public, a receiver giving really good volume and quality from home and abroad.

Running Cost

The running cost of this set is

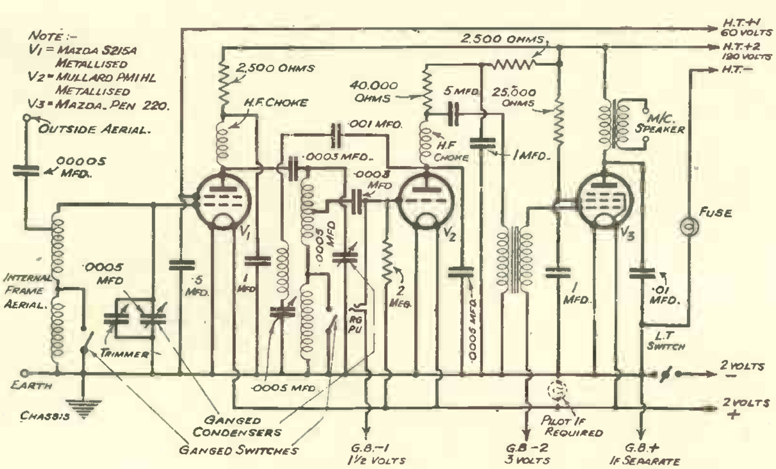


Fig. 23.—Theoretical Circuit Diagram of Burgoyne Dreadnaught Three Receiver.

very low indeed, and the high-tension battery supplied will last, with proper care, at least three to four months. The accumulator, when fully charged, will give from twenty to twenty-five hours' service.

The method of putting the receiver into operation can be described in very few words, owing to its extreme simplicity.

The battery connections should be looked over, and any loose plugs or connections should be made firm.

To operate, the switch should be turned to either L or S, signifying long or short waves respectively, and the volume knob turned slowly clockwise. This will bring the receiver into a state of gentle oscillation, and carrier waves or whistles should be encountered upon rotating the main tuning dial.

Any one of these carriers can be resolved into speech or music by reversing the action of the volume control and retuning slightly on the illuminated dial.

Faults

The majority of points for finding faults outlined in the paragraphs of the "Popular 3" receiver will also apply to this model.

The main difference between these models is, whereas in the case of the "Popular 3" reception is limited to the medium-wave band, the range of the "Olympic 3" covers both long and medium wavelengths.

Operating Details

Batteries fitted as standard :—

H.T. battery—

Drydex H.1025 {H.T. 90 volts / GB. 9 volts} In one unit.

L.T. accumulator—

Exide DTG. 2 volts.

Valves fitted as standard are as follows :

THE DREADNAUGHT THREE

This instrument is of the steel-chassis built type, and embodies all the latest features of a high-class instrument of this character. A high-magnification screen-grid valve handles signals supplied by an internal frame aerial, and from thence to a high-sensitivity detector stage, and finally to a high-efficiency output valve, which is accurately matched to a moving coil speaker.

No difficulty should be found in operation, for the controls have been reduced to the utmost simplicity, and the tuning scale, being marked in wavelengths, facilitates precise tuning or long-distance searching at will.

The lower left knob places the instrument in a condition for the reception of long- or medium-wave programmes by rotation in the appropriate direction. The lower right-hand knob controls the degree of volume, and also maximum sensitivity for long-distance reception.

An additional and important feature of this set is the incorporation of facilities for the connection of a radiogram pick-up, enabling enjoyment to be obtained of one's own choice of records.

Servicing Notes

As far as service goes, very little attention is required outside of the occasional replacement of the battery power supply. Owing to the low consumption figure, the high-tension supply should last at least four months, whilst the low-tension accumulator will provide thirty-six hours' entertainment at one charge.

The plugs and spade terminal connections of the flexible wires should be kept clean, and if necessary sprung open a little more, to ensure good contact being made in the respective sockets. Care must be exercised in the replacement of plugs

Valve.	Make.	Type.		Lead.	Approx. Voltage.	Approx. Milliamps.
Detector . .	Cossor	HF210	Metallised	H.T.+1	63	1·0
L.F. . . .	,,	LF210	,,	H.T.+2	81	1·4
Power . .	,,	P215		H.T.+3	90	3·0
				G.B.−1	−3	
				G.B.−2	−6	
	Total consumption					5 to 6

in the correct sockets, especially so in the case of the grid bias plug marked G.B.—2, as good quality reproduction is mainly dependent on this important connection.

The radiogram attachment is operated when the switch is in either position for radio programmes, and the complete functioning is brought automatically into effect by the insertion of a plug into the jack provided on the back of the case. Two wires, preferably of screened cable, should be taken from the plug referred to and connected to the volume control terminals of the pick-up. As no provision is made for volume control on the receiver, it is preferable to have this incorporated with the particular make of pick-up in use, and the greater the sensitivity of the latter, the more is the need felt for the former.

Operating Details

Further and final points that need special emphasis are that replacements of batteries or valves should only be made with the types and values specified, and that satisfactory results cannot be expected if these suggestions are not adhered to. The following are the details for replacements :—

L.T. accumulator .	Exide FWJ7.
H.T. battery .	Drydex 1039A.
Screen grid valve .	Mazda 215A Metal, or Mullard PM12A.
Detector . .	Cossor 210H.F.
Output . .	Mazda, Pen. 220.

THE CLOCK RECEIVER

The combined efficiency of components and modern valves have made it possible to place a straight-three receiver before the public, giving really good volume and quality from home and abroad.

The running cost of this set is very low indeed, and the high-tension battery supplied will last three or four months. The accumulator, when fully charged, will give from twenty to twenty-five hours' service, thus providing about three and a half continuous hours' use per day per week.

The method of putting the receiver into operation is identically the same as described under the instructions given for the Burgoyne "Olympic 3."

The faults liable to be met with are very few, and as a rule, if the receiver refuses to function, will generally be found in either the batteries or their connecting plugs. These should be kept clean and the ends splayed a little to ensure good contact in the sockets.

The general wiring of the receiver should not be interfered with. If the set be damaged by mishandling it should be returned to the manufacturers, where expert attention will soon put matters right.

Operating Details

Batteries fitted as standard are as follows :—

H.T. battery—

Drydex H.1025 {H.T. 90 volts / G.B. 9 volts} In one unit.

L.T. accumulator—

Exide LCJ4. 2 volts.

Valves fitted as standard are as follows :—

Valve.	Make.	Type.		Lead.	Approx. Voltage.	Approx. Milliamps.
Detector . .	Cossor	HF210	Metallised	H.T.+1	63	1·0
L.F. . . .	,,	LF210	,,	H.T.+2	81	1·4
Power . .	,,	P215		H.T.+3	90	3·0
				G.B.—1	—3	
				G.B.—2	—6	
	Total consumption .	.	.	. . .		5 to 6

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION X—THE PRINCIPLES OF WIRELESS WAVES

NOW, when we have a fair idea of the behaviour of coils and condensers in electrical circuits, and are thus ready to assimilate the principles of the tuning circuit in a wireless receiver, it is necessary to make a halt in our studies and see what part of Nature's mechanism comes into play between the transmitting and the receiving aerial.

The Importance of Understanding Theoretical Principles

In studying the art of radio communication, one cannot take a merely parochial view of the subject. There are many so-called "wireless amateurs," and even "practical experts," who have no time for theory, and are merely concerned with purely practical problems. Such an attitude to radio is futile, as no one can become a sound practical wireless man without full understanding of the theoretical principles underlying the art.

The question of wireless waves is highly important to every serious student, and unless he has a thorough understanding of the nature, generation, propagation and detection of wireless waves the whole subject of wireless will remain a closed book. (Readers are also advised to study Sir Ambrose Fleming's article on this subject on p. 393.)

What a Wireless Wave is

We already know that a wireless wave is a combination of an electric and a magnetic field, changing in intensity and direction in step and flying through space with the tremendous velocity of 186,000 miles per second, or 300,000,000 metres per second. This is a remarkable natural phenomenon. Energy is being propagated through space with immense speed, an electric and a magnetic field having acquired this energy from electrons moving to and fro at some point of space will traverse this space and cause electrons to move at another point.

In order to understand the mechanism of this exchange of energy we have to consider three things: the space, energy and the wave.

What is "Space"?

Modern science is far from being sure what this space is. There are two schools of thought. The first and the older school thinks that space is filled with—so-called—*ether*, which is a medium possessing, as yet, unknown properties, properties which are so unusual and so foreign to matter that it is impossible either to prove or disprove their existence and their nature. The second school of thought denies the existence of ether, and assumes space to be a mere emptiness which has properties such as only highly trained mathematicians can explain with the help of mathematical symbols without understanding in the least what this space is. During the last few years, in the absence of real experimental proofs, speculation has been running wild, and most weird ideas have been formed about space, ideas so strange that only a few of the "chosen ones" were able to follow them.

In spite of this unseemly scientific confusion, it is possible to form some sort of idea of space by accepting some of the more intelligible ideas brought forward during the last few years.

A Vast Globe of Ether

Several scientists have advanced the view that space is both finite and unbounded. If you imagine this space as a vast globe of ether you will realise what the above statement means. A globe or a sphere has definite dimensions. It is finite. But it is unbounded, because one can travel on the surface of a globe without ever coming to the "end" of it. How vast this finite and unbounded space is can be realised from the following. Light, which is supposed to be a wave of the same nature as the wireless wave, *i.e.*, an electromagnetic wave, consisting of two fields, is propagated in space with the same velocity as the wireless wave. It has been estimated that if a ray of light travelling with the speed of 186,000 miles per second were sent right round the circumference of the globe of space or ether it would take 500,000,000,000 years to go round!

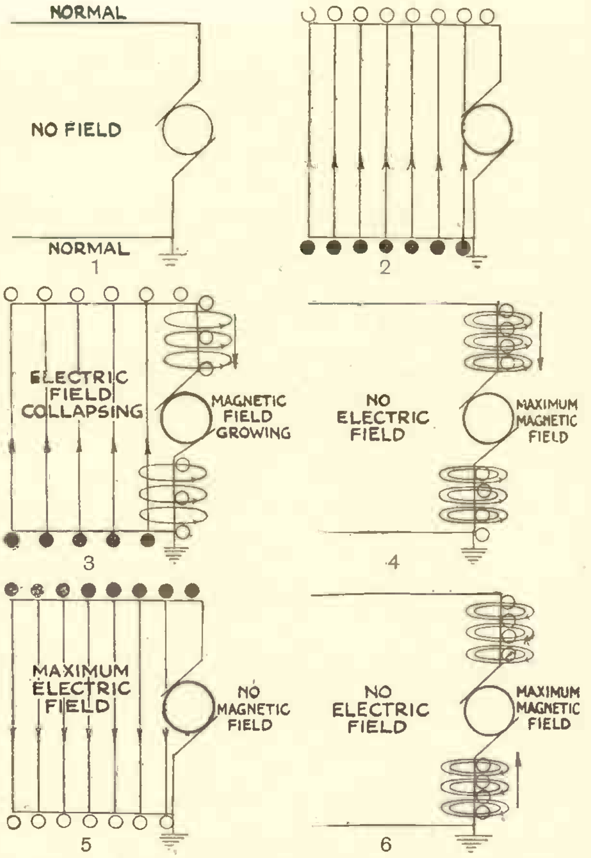


Fig. 1.—The Electro-magnetic Effect between an Aerial and Earth

1 shows an alternator connected to aerial and earth. 2 shows how the aerial becomes charged with electrons during the first half wave. 3 shows how the aerial begins to discharge when the alternating voltage begins to drop. The completion of the cycle is shown in Figs. 4, 5, and 6.

scientists call the electron and the proton *wavicles*.

If this be true and the electron and the proton are made up in the first place from a stress and a strain in the ether, *i.e.*, made up of an electric and a magnetic field, then it is clear why both the electron and the proton should have an electric field around them, *i.e.*, why the ether around them should always be strained, and why such a particle in motion should produce a magnetic field.

The only Established Facts

However, all this is merely speculation on the part of the scientists with the only facts established, more or less soundly, that there is some mysterious medium which we call ether, that there are electrons and protons, that both the electron and the proton have an electric field around them, be they at rest or in motion, and that both have a magnetic field around them when they are in motion but not when they are at rest.

Why Electrons and Protons are sometimes called Wavicles

Thus it would appear that in the first place this vast globe of ether was created, and quite possibly a number of such globes and energy was communicated to the ether. This energy produced certain changes in the primordial mass, and created a vast number of pairs of "material" particles, particles which we call electrons and protons. Ideas have been brought forward which assume both the electron and the proton being a sort of "solidified" ether waves, waves which somehow became permanent. For this reason some

Sir Oliver Lodge's description of the Present State of Affairs

Of the ether itself we know very little (by the way, this ether of ours has nothing to do with the stuff in chemists' shops). We are learning by degrees of its behaviour from our studies of the behaviour of electro-magnetic waves. Sir Oliver Lodge very aptly described the present state of affairs by saying that the modern scientist resembled a costermonger with a shrouded animal between the shafts of a donkey cart. The costermonger does not know whether the shrouded animal is a dog, a zebra, or a donkey, and can only infer its nature from its more or less tractable behaviour.

As far as we are concerned, the ether is something carefully shrouded in so large a shroud that we cannot even feel the contours of our " animal."

Properties of the Ether

It is, however, suspected that whatever properties the ether may have, these properties are such that it is difficult even to imagine them on our tiny human scale. It is said, for instance, that ether possesses an internal pressure of the order of 1,000,000,000,000,000,000,000,000,000,000,000 units. If ether is to be judged by human standards its density must be colossal, much greater than that of any solid body we know of. And yet, in spite of such tremendous density, little electrons and protons can wind their way through it at tremendous speeds. The ability of the ether to regain its original condition after being disturbed or deformed, a property which we usually call elasticity, must also be enormous.

Well, whatever its properties are, periodic disturbances or waves can be produced in the ether, waves with many of which we are familiar, and some of which can be produced artificially by human effort.

How Energy is Propagated in Space

Now, let us see how energy is being propagated in space. Even without taking into consideration the unusual properties of ether, it is clear that if ether is to be disturbed in some way or other a certain amount of work must be performed in order to produce such a disturbance. A transmitting aerial disturbs ether. What sort of work is done to produce such a result ?

Well, electrical energy is being communicated to the aerial. This electrical energy is the result of transformation of either the chemical energy in accumulators or mechanical energy in the case of an alternator or a dynamo. Either chemical or mechanical work must be done in order to cause electric currents to flow in the aerial. This chemical or mechanical energy is transformed into electrical energy, and the electrical energy is expended on producing electro-magnetic waves in the ether. Thus, every electro-magnetic wave travelling through space will be in possession of a certain amount of energy.

Each Electro-magnetic Wave Possesses a Certain Quantity of Energy

This being so, we can say that each electro-magnetic wave possesses a certain quantity of energy, or a *quantum* of energy, as the scientists call it, a quantum being a definite amount of energy capable of doing a definite amount of work.

But there are disturbances and disturbances in the ether. Some electro-magnetic waves are longer than others (the number of waves which can occur in a second varies considerably with the nature of the wave. Every wave covers a distance of 300,000,000 metres in a second. While doing this it is undergoing its periodic variations, the electric and the magnetic fields growing and collapsing, and thus taking place within a certain length of space. If 1,000,000 waves are occurring in one second and the wave spreads with a velocity of 300,000,000 metres per second, it is clear that each wave will be $\frac{300,000,000}{1,000,000}$, *i.e.*, 300 metres long).

The Smaller the Wavelength the Larger the Amount of Energy

It is easily understood that since the wavelength differs with various kinds of waves, different amounts of energy or quanta have to be expended in producing various wavelengths. For this reason, the quantum of energy associated with every kind of wave is different. It is curious, but, nevertheless, it is a fact, the smaller the wavelength the larger is the amount of energy associated with each wave, so that the most energetic waves are the shorter waves. A wireless wave has less energy associated with it than a light wave. We shall see a little later how they differ from each other in wavelength.

This energy, or ability to perform work, is not something abstract, but a very real thing. An electromagnetic wave can do work and it can do some damage too, if not properly controlled. I think that those who have been badly sunburned at the seaside will know what damage a light and heat wave can do.

Different Kinds of Ether Waves

Let us investigate these ether waves and see how many different kinds there are, and how their behaviour differs in each case. Mark you, we do not yet know *all* the ether waves. There are many, as we know from the gaps in our wavelength table, that are still unknown.

Cosmic Rays

The shortest electro-magnetic wave is that belonging to the so-called *cosmic rays*. These are the rays which the Belgian professor Piccard investigated when he went up in his now famous balloon into the stratosphere (the region beyond the atmosphere).

Cosmic rays are supposed to be electromagnetic waves produced by electrons and protons combining into atoms in the depths of the atmosphere (Millikan). When an electron comes nearer to a proton it loses some of its energy by being jerked from its line of flight into the orbit around the proton. The electron thus loses some of the quanta of energy it possesses and thus radiates waves which have a wavelength of the order of $\frac{3}{10,000,000,000,000,000}$ metre. There are three kinds of cosmic rays having different wavelengths. This is the most penetrating ray known to science. The energy associated with the cosmic ray wave is so great that it is felt through several feet of lead and is capable of breaking up atoms when the wave reaches them.

Gamma Rays

Of slightly longer wavelength are the so-called *gamma rays* which are electromagnetic waves radiated by electrons within the disintegrating atoms of radioactive substances. These rays which are natural rays, are of the same nature as the *X-rays*, which are produced artificially. Both these rays are caused by electrons being suddenly stopped by an obstacle. Although the gamma and the X-rays are not as penetrating as the cosmic rays, still they will penetrate through a few inches of lead. Both these rays falling upon a metallic body will cause an electron emission from the surface of the metal, in other words, the gamma and X-rays will knock electrons out of the surface atoms. Here is the first instance of an electromagnetic wave causing a disturbance of electrons in a metallic conductor.

Ultra-violet Rays

Next come slightly longer waves of the so-called *ultra-violet rays*. These have a wavelength of the order of one ten-millionth of a metre. These rays, in common with X-rays, will affect a photographic plate and will cause what we know as "sunburn." Ultra-violet rays, in common with ordinary light rays, are capable of lowering the resistance of air, the resistance of selenium and also the resistance of space between the cathode and the anode of a photoelectric cell.

The Spectrum

After the ultra-violet rays come the violet, indigo, blue, green, yellow, orange and red rays of ordinary sunlight, coloured rays which combine into the "white" light from the sun. This is the reason why, when a ray of ordinary sunlight is made to pass through a prism, the various coloured rays, being of different wavelengths, are passed by the prism with different speeds, so that a ray of white light is spread out into a coloured band which is called a *spectrum*. The human eye is capable of detecting light rays and differentiating between the various colours.

Infra-red Rays

After the light rays which have a wavelength of the order of a millionth of a metre, come the so-called *infra-red rays*, or heat rays, with a wavelength of $\frac{1}{100,000}$ of a metre.

Wireless Waves

Now we come to wireless waves which begin at wavelengths of the order of a thousandth of a metre or a tenth of a centimetre. Generally speaking, wireless waves cover a range of wavelengths from 1 cm. to 100,000 metres and even more, but for practical purposes the following wavelengths are used :—

Very short waves (ultra short waves)	Below 10 metres
Short waves	From 10 to 15 metres
Intermediate waves	From 50 to 200 metres
Medium waves	From 200 to 3,000 metres
Long waves	From 3,000 metres

This is the recent classification of the International Consultative Committee for the technique of radio electric communication.

Confusion between Short and Medium Waves

The homely method of classifying wireless waves adopted both by amateurs and manufacturers, a method leading, by the way, to a good deal of confusion, is as follows :—

Short waves	Up to 100 metres
Medium waves	Up to 600 metres
Long waves	From 1,000 metres upwards

Some manufacturers state in their literature, in describing a set, that it will deal with both short and long wavelengths, meaning the respective bands of 225 to 550 and from 1,000 to 2,000 metres. The reason for confusion is obvious.

All Ether Waves belong to the Same Family

Thus, as we see, all ether waves are really " wireless waves " in that they are being propagated in space without any intervening material conductors. Or to put it another way, all ether waves belong to the same family, they are a result of combination of an electric and a magnetic field, they are all caused by some activity of electrons in masses of matter, all borrow their energy from the electrons and are all capable of disturbing the electrons in the atoms of matter which they happen to encounter on their journey.

Why Wireless Waves Possess the Weakest Quanta

From the point of view of quanta of energy associated with each kind of a wave the wireless waves, being the longest, possess the weakest quanta, *i.e.*, amounts of energy which can only move electrons to and fro in a conductor but are unable to displace them from the conductor as the cosmic and X-rays are doing.

This is fortunate from our point of view as this comparative weakness of quanta of energy associated with the wireless waves gives us an opportunity of controlling both the despatch or radiation of wireless waves and their detection.

If you glance through the only official list of wavelengths of World Broadcasting stations in *World Radio* published by the B.B.C. (now the Empire Journal) you will see that the wavelengths in use in broadcasting cover a band from 13·92 metres on short waves (Pittsburgh W8XK, Frequency 21,540 kilocycles) to 1,935 metres (Kaunas, Lithuania, Frequency 155 kilocycles). These are the wavelengths used in practice in broadcasting.

There is a good deal of difference in behaviour between the longer and the shorter wavelengths, and we shall study this question in the next section when we are dealing with the generation and propagation of wireless waves.

Wavelengths and Frequencies

In the meantime let us fix our ideas on the question of wavelengths and frequencies.

If we are sending out a wireless wave from a transmitter in such a way that only one complete wave occurs in one second, *i.e.*, during the second both the electric and the magnetic fields start from zero, increase to a maximum, fall down to zero again, change their direction, grow to a maximum and fall to zero, thus undergoing one complete cycle of events, we shall have a wave of a length of 300,000,000 metres and having a frequency of occurrence equal to unity.

General Rule for Finding Wavelengths

If two waves occur in a second, the length of each wave will be $\frac{300,000,000}{2}$, or 150,000,000 metres, and the frequency of the wave will be 2. If ten waves occur in one second, the length of each wave is $\frac{300,000,000}{10}$, or 30,000,000 metres. You have no doubt noticed that in order to find the wavelength of a wave I always do the same thing: take the speed of the wave which is 300,000,000 metres, and divide it by the frequency with which the wave is occurring.

Thus we can put down a general rule for finding wavelengths :—

$$\text{wavelength equals } \frac{\text{speed of light}}{\text{frequency}}$$

Since the speed of light is the speed of all ether waves and is therefore always the same, *i.e.*, constant, we can put down :—

$$\text{wavelength} = \frac{300,000,000}{\text{frequency}}$$

Now it is usual in mathematical shorthand to use a symbol λ (Greek letter lambda) for the word wavelength and the letter f for frequency so that the above equation can be written briefly as

$$\lambda = \frac{300,000,000.}{f}$$

Similarly, if we know the wavelength and do not know the frequency we can write :—

$$f = \frac{300,000,000}{\lambda}.$$

What Frequency Means

Thus, frequency means merely the number of times a complete cycle of events of an electro-magnetic wave takes place each second, or, in other words, how many times a given wave occurs each second. Therefore, when you see the frequency in a table of stations you will know what the word cycles means. But in the case of very short waves when the frequency must be large the numbers expressing the frequency in cycles become very cumbersome. And for this reason a new unit was invented, a *kilocycle*, 1 kilocycle being equal to 1,000 cycles. Thus "10 kilocycles" means simply 10,000 cycles.

Wavelength, as you have noticed, is usually measured in metres. If you take the wavelength table in *World Radio* and check up on the figures of wavelengths and frequencies you will get some useful exercise. If a wavelength of 300 metres has a frequency of 1,000 kilocycles placed against it, divide 300,000,000 by the frequency *in cycles*, and see if the stated wavelength is right.

QUESTIONS AND ANSWERS

What is the Speed with which Wireless Waves Travel?

They travel at the rate of 186,000 miles per second, or 300,000,000 metres per second.

What is the Curious Fact about this Figure?

It is exactly the same as the speed of light.

Are Light Rays and Wireless Radiations Related?

Yes; both are said to consist of waves in the ether, the difference between them being that, whilst wireless radiations have wavelengths of from 1 to 10,000 metres, light rays have wavelengths which are measured in small fractions of a millimetre.

Is there any Relation between Wavelengths and the Energy Radiated?

For a given amplitude the shorter the wave the larger the amount of energy associated with it.

What are Cosmic Rays?

Rays which reach the earth from distant parts of the universe. They have a wavelength much smaller than the range of light rays and possess enormous penetrating power.

What are Ultra-violet Rays?

These are intermediate in wavelength between cosmic and light rays.

DISTORTION

ITS CAUSES AND SOME CURES

By HARLEY CARTER

IF the sounds produced by a loud speaker differ in any way from those presented to the microphone in the studio, distortion of one kind or another has been introduced somewhere in the chain of apparatus comprising the transmitting and receiving equipments. This definition of distortion is very wide, and, strictly speaking, a certain small amount of distortion must always be present, because it is inconceivable that the whole of the transmitting apparatus and every portion of any given receiver shall be mathematically perfect and 100 per cent. efficient.

In practice, therefore, a somewhat more restricted idea of distortion must be entertained, and the listener, realising that a receiver of ordinarily good design, correctly operated, will give a truly excellent performance, may fairly consider that, if the reproduction from his set is harsh, unnatural or in any way unpleasant, avoidable distortion has been introduced.

Distortion can, of course, occur at any stage between microphone and loud speaker, but it can be taken for granted that, except in occasional moments of emergency, the programme as radiated from the B.B.C. stations is as near perfection as is humanly possible. Suspicion, therefore, must always fall on the receiver when reproduction falls short of the expected standard.

How Distortion is Caused

The principal causes of distortion are, first, unsuitable values of components or components of faulty design; second, overloading of some portion of the apparatus; third, incorrect operating conditions.

To deal with causes falling in the first category would entail a complete treatise on set design and the selection of components—matters which are treated fully in other sections of "COMPLETE WIRELESS." It will therefore be assumed, for the purposes of this article, that the set has been correctly designed and assembled, and that the components and valves are suitable for the purposes for which they are used.

What may be termed the "preventable" causes of distortion mainly occur under the heading "overloading," and this may take place in almost any portion of a receiver.

Overloaded Valves

One of the most

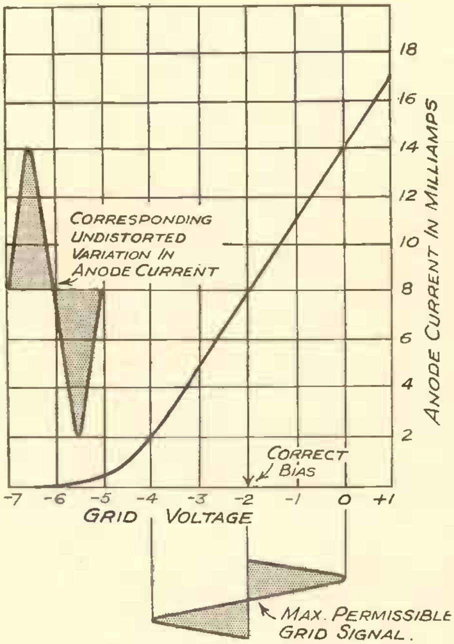


Fig. 1.—GRAPH SHOWING GRID VOLTS/ANODE CURRENT CHARACTERISTIC OF TYPICAL 3-ELECTRODE AMPLIFYING VALVE.

Also illustrating undistorted amplification when valve is correctly biassed.

frequently occurring forms of overloading is that of valves. By overloading in this case is meant applying to the grid of a valve a signal voltage greater than that which it can handle without producing distortion. In all types of amplifying valve, the signal applied to the grid takes the form of an alternating voltage corresponding in frequency to the radio wave transmitted from the broadcasting station, or to the audio-frequency modulation of that wave. The alternating signal voltage (or grid input voltage) produces variations in the anode current of the valve. If amplification is to be free from distortion, the anode current variations must be strictly proportional to the grid voltage variations.

Now in every valve this true proportionality exists over a certain range of values of grid voltage. For example, the diagram reproduced in Fig. 1 shows the relation between instantaneous values of grid voltage and anode current for a typical low-frequency amplifying valve, and it will be observed that between the limits of 0 and − 4 volts on the grid, the anode current is directly proportional to the grid voltage. For higher negative values of grid voltage, the "curve" is not straight, and true proportionality disappears.

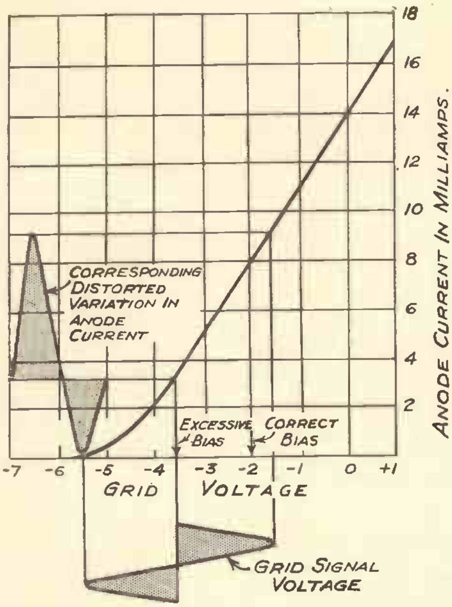


Fig. 2.—GRID VOLTS/ANODE CURRENT CHARACTERISTIC OF 3-ELECTRODE AMPLIFYING VALVE.

Showing how distortion is introduced by over-biassing.

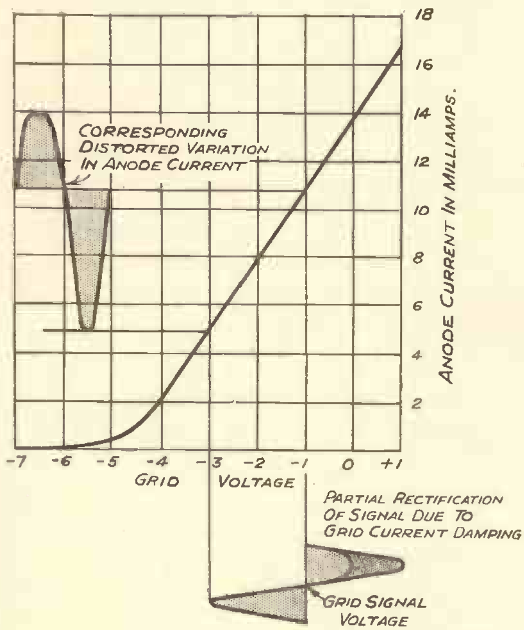


Fig. 3.—GRID VOLTS/ANODE CURRENT CHARACTERISTIC OF 3-ELECTRODE AMPLIFYING VALVE.

Showing distortion due to under-biassing.

In order to obtain undistorted amplification with this valve, therefore, it would be necessary to apply a steady negative grid bias of about 2 volts to the grid, and to keep the amplitude of the incoming signal within the limits of 2-volts peak value.

Incorrect Bias

Distortion in an amplifying stage can occur if any of three conditions occur: first, if the valve is correctly biassed, but a signal of excessive amplitude is applied; second, if the valve is over-biassed so that the incoming signal voltage overlaps the bend of the characteristic curve; and third, if the valve is under-biassed so that during one half of each signal wave the grid becomes positively charged.

Fig. 2 illustrates the effect of over-biassing a valve, while Fig. 3 gives the result of under-biassing. In this case, the grid becomes, during a part of every signal cycle, positive with respect to the filament. Current will therefore flow in the grid circuit and exercise a damping effect on the signal.

Scratching and High-pitched Reception

In all cases the effect is the same—partial rectification of the incoming signal occurs owing to unequal amplification of the positive and negative halves of the signal. If the resultant variations in anode current are analysed mathematically, it can be shown that such partial rectification is equivalent to the introduction of what musicians call "harmonics," that is to say, notes having a frequency two-, three-, four-times or some other multiple of the fundamental frequency. As a result, the reproduction sounds high pitched, and even scratchy; individual instruments lose their characteristic "timbre" and the whole quality of the sound is unnatural.

First Step in Remedying Distortion

The first step in attempting to remedy distortion, therefore, is to check the grid bias of each valve to see that it accords with the value recommended by the valve maker. In this connection, it should not be assumed that, because the grid bias lead is plugged into the socket marked, say, 6 on the grid bias battery, a bias of 6 volts is really applied. An old grid bias battery may give very much less than its nominal voltage, and may require renewal. Neither should a voltmeter of ordinary low resistance be used to test the battery, for the current taken by the instrument will cause an erroneous and low reading.

Testing Grid Bias with a Milliammeter

The only safe method of checking up the bias is by means of a milliammeter inserted in the anode circuit of the valve under examination. The reading of the milliammeter should agree with the maker's quoted value of anode current at the working anode voltage and working bias voltage. A table giving these values is usually printed in the valve manufacturer's catalogue and is always included on the instruction sheet issued with every valve.

The diagram reproduced in Fig. 4 shows how a milliammeter should be connected in the anode circuit for this purpose. The instrument should be of reliable make and of the moving coil type. If the reading is appreciably higher than that quoted by the valve maker, the bias should be increased. Similarly, if the reading is too low, bias should be reduced. If all is well, the needle will remain steady or, rather, should oscillate slightly above and below the mean value of anode current. Distortion will be indicated by more or less violent fluctuations in the anode current reading. An upward "kick" indicates over-biassing, and a downward kick is the symptom of under-biassing. The reasons for this will be obvious from further reference to Figs. 2 and 3.

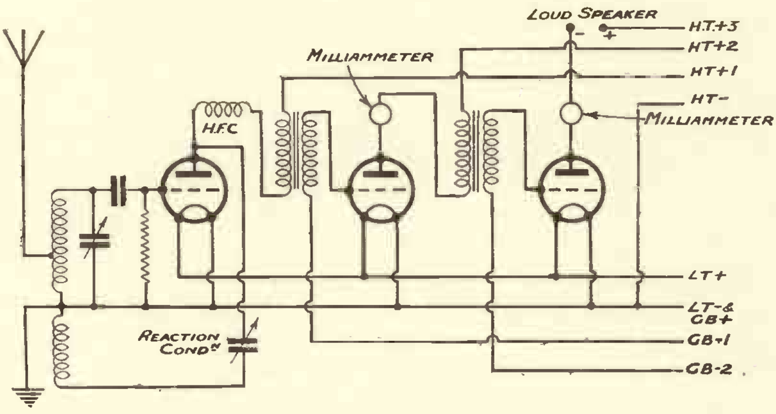


Fig. 4.—DIAGRAM OF TYPICAL RECEIVER SHOWING POINTS AT WHICH A MILLIAMMETER SHOULD BE INSERTED TO CHECK THE ANODE CURRENT OF AMPLIFYING VALVES.

How Overloading is Indicated

If the grid bias voltage is apparently cor-

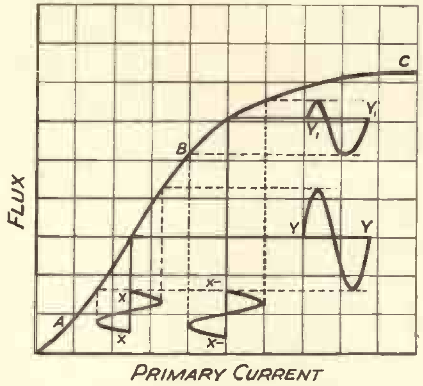


Fig. 5.—Showing relationship between Primary Current and Magnetic Flux in an Iron-cored Transformer.

rect and distortion still persists, the input to the valve should be reduced by means of the volume control. Restoration of good quality will at once indicate that the trouble was the overloading of a correctly biassed valve.

Loss of Emission

A similar kind of distortion may occur if a valve, through old age or over-running, has lost a large proportion of its emission. In this case, it will be found when testing the anode current that, no matter how the grid bias is adjusted, the reading of the milliammeter will be lower than the normal rated current of the valve. Bad distortion and loss of power can usually be traced to this cause, and the only remedy is to identify the offending valve and to replace it with a new one.

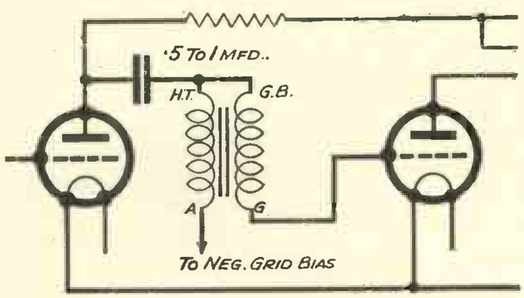


Fig. 6.—Diagram to illustrate Resistance-feed Transformer Coupling.

The effective transformer ratio is (R + 1) to 1, where R = turns ratio.

Overloading of Amplifying Valve

Overloading of an amplifying valve is chiefly liable to occur in a high-frequency stage or in the output stage. In the case of the high-frequency valve, distortion may be noticeable only when listening to the local or other powerful transmissions, in which case the application of some form of input volume control will afford a remedy. If the distortion is general and is accompanied by instability, the value of the screen voltage should be checked.

Distortion in the Output Stage

Distortion in the output stage is usually the result of using an unsuitable type of output valve. A valve of the so-called "power" class is intended to give the maximum volume from the comparatively weak signals available in portable or 2-valve domestic receivers. If any other amplifying stage is provided, either high-frequency or low-frequency, it is probable that, at any rate when receiving the local station with a good aerial, the power valve will be overloaded. In such circumstances it is necessary either to make use of a volume control for local station work, or to fit a "super-power" valve which is designed to handle greater inputs. With a super-power valve, the volume on weak inputs will be less than with the "power" valve, but with large inputs, big volume and good reproduction will be obtained.

If big volume, combined with good quality, is desired with weak inputs, a pentode output valve should be fitted, but here again there is risk of distortion if, owing to the existence of previous amplifying stages, powerful grid input voltages are applied to the pentode, and a volume control must be provided to safeguard against this form of overloading. It is advisable to use only one stage of L.F. amplification with a pentode valve.

Detector Distortion

Quite a large amount of distortion can be introduced at the detector valve. In fact, this stage must be very carefully designed and adjusted if it is to work efficiently and without distortion. There are three forms of valve detector.

In the "anode bend" detector—not very frequently used in modern commercial receivers—grid bias is applied to the detector and rectification occurs at the "bottom bend" of the grid volts/anode current characteristic—in fact, in the anode bend detector, we are deliberately obtaining the effect which follows the over-biassing of an amplifier. Unless, however, the incoming signals are fairly strong, the efficiency of rectification is low, and distortion will occur, due to incomplete rectification.

Distortion in Leaky Grid Detectors—

The most common form of detector is the "leaky grid" detector, where the

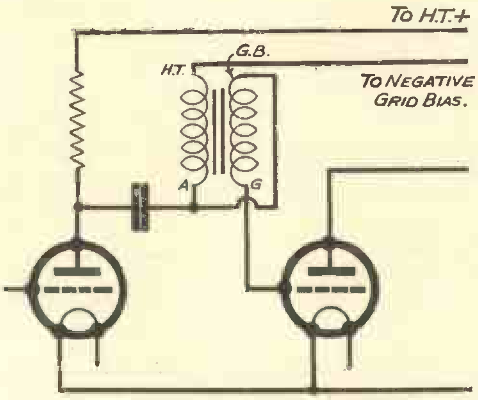


Fig. 8.—Alternative arrangement of Resistance Feed.
Giving a ratio less than the turns ratio.

grid is given no bias or a slight positive bias. Here we obtain rectification in a manner similar to that which causes distortion in an under-biassed amplifier. Distortion may occur here if the signal applied to the detector is too great, for there will be a risk of "double rectification" under a combination of leaky grid and anode bend conditions. Power grid detection is a form of leaky grid detection, using higher anode voltages and lower values of grid condenser and leak. Very perfect rectification can be obtained, and owing to the longer grid base available at the higher anode voltage, the risk of double rectification is avoided.

—and How to Cure it

In practice, therefore, detector distor-

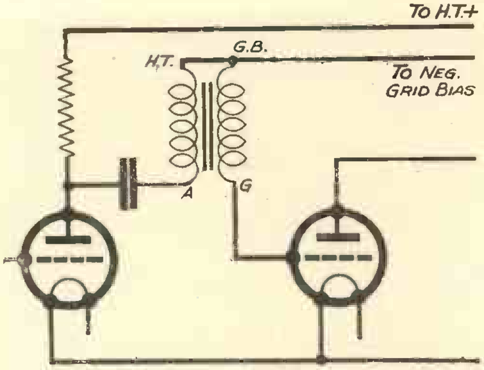


Fig. 7.—Alternative arrangement of Resistance Feed.
Giving normal strength ratio.

tion will be only experienced in sets employing a leaky grid detector. Reduction of the input may affect a cure, pointing to overloading as the cause of the trouble. If distortion still persists, the grid leak should be examined for internal breakdown—substitution is the best method of test—and the grid condenser may also receive attention. It is assumed that the listener will first ascertain that the distortion is not due to excessive reaction.

Distortion due to Transformers

Valves are not the only portions of a radio equipment liable to overloading. Very similar troubles, with consequent distortion, can occur if such a component as a low-frequency intervalve transformer be compelled to carry a current

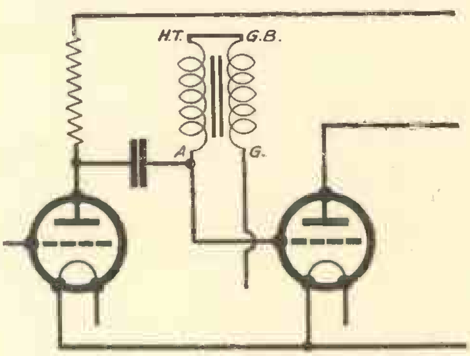


Fig. 9.—Alternative arrangement of Resistance Feed.
Giving a 1-1 ratio.

greater than that which it is intended to handle.

Relationship between Primary Current and Magnetic Flux

The relationship between the primary current (which is, of course, a measure of the magnetising force) and the magnetic flux in an iron-cored transformer is represented by the graph reproduced in Fig. 5, and it will be observed that, although the graph is substantially linear over a considerable region (A–B), saturation conditions make themselves manifest over the portion B–C.

The secondary voltage which, in the low frequency intervalve transformer, is applied to the grid of the following valve, depends upon the rate of change of flux. If the mean and peak values of the primary current are such that they always subtend the linear portion of the magnetisation curve, no distortion can occur. This state of affairs is indicated on the graph, XX representing the variations in primary (anode) current, and YY the corresponding variations of flux.

But if the mean working primary current is too great, as at X–X–, the effect of magnetic saturation is to produce the asymmetrical variations of flux indicated at Y1Y1, and the secondary voltage of the transformer will show similar distortion.

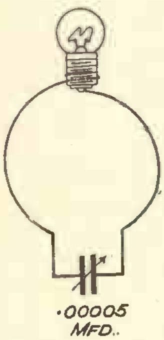


Fig. 10.— Arrangement of Exploring Coil for Detection of H.F. Oscillation.

Early types of transformer of good design, having ordinary iron core stampings, were capable of carrying the normal anode current of a detector or low-frequency amplifying valve without saturating the core; but in cheaper transformers the core was cut down to unduly small dimensions, and were, therefore, very liable to saturation troubles. A similar risk of saturation occurs with modern high-efficiency transformers, the cores of which are composed of special high permeability alloy stampings. In this case, however, the trouble is not due to bad design, but is a natural corollary of the higher efficiency of the components, and to the present tendency to use "power-grid" detection which involves running the detector valve at a comparatively high value of anode current.

Using Resistance Feed

Fortunately it is not difficult to avoid risk of distortion in these cases, the solution being the resistance-feed arrangement. This can be considered as a combination of resistance-capacity and transformer coupling, the connections being as shown in Fig. 6. It will be observed that a high resistance is included in the anode circuit of the first valve, while the anode is coupled to the low-frequency transformer by a condenser which should be of comparatively large capacity—of the order of 1 mfd. The effect of the arrangement is to filter out the direct current component of the anode current from the primary circuit of the transformer, so that only the audio-frequency variations pass through the winding. The value of the anode resistance is not critical, but should be from two to five times the anode impedance of the valve.

Methods of Connecting a Transformer

There are several methods of connecting the transformer. That shown in the diagram is recommended. Here the transformer is so connected that it operates as an auto-transformer having a ratio greater than the turns ratio. Thus, if the normal ratio of the transformer is 3 to 1, the effective ratio when used as in the diagram will be 4 to 1. Alternative arrangements are given, Fig. 7 giving the normal step-up ratio, Fig. 8 a ratio less than the turns ratio, and Fig. 9 a 1 to 1 ratio. In the latter arrangement the transformer acts merely as a low-frequency grid choke.

Choke Feed

One disadvantage of the resistance-feed method is that it reduces considerably the effective anode voltage of the valve, and this may be serious in equipments where the total high-tension voltage available is limited. In such cases, however, choke feed may be employed, a low-frequency choke of some 300 henries inductance being substituted for the anode resistance.

Distortion due to High-frequency Oscillation

In view of the growing use of mains-driven receivers and amplifiers having powerful output stages capable of delivering several watts of audio-frequency power, the possibility of distortion due to the building up of high-frequency oscillations in the low frequency stages has assumed considerable importance. Such oscillation is not due to portions of the original radio-frequency signal surviving to reach the low-frequency amplifier, but to oscillations actually generated in the circuit itself.

Symptoms of High-frequency Oscillation

Parasitic high-frequency oscillation is manifested by serious distortion accompanied by a reduction in volume and an increase in anode current, the latter not infrequently reaching alarming proportions.

This trouble usually occurs in amplifiers fitted with highly efficient modern output valves, and more particularly when the output stage consists of valves arranged in push-pull or in parallel. It is not due to any fault in the valves, but results from the very high efficiency of the valves as indicated by the large value of the mutual conductance of modern output valves. More especially does it occur when modern high slope valves are used in amplifiers of old design which were originally intended for use with less efficient types of valve. What actually happens is that a transient signal of considerable amplitude occurs, and is amplified by the output stage. Then, because of some stray capacitative coupling between the grid and anode circuits, energy is fed back to the grid circuit and reamplified. It may happen that the electrical constants of the circuit are such that its natural period corresponds to a wavelength of a few centimetres, and once oscillation commences very high amplitudes are generated. This frequently occurs where the wiring of the set is laid out symmetrically.

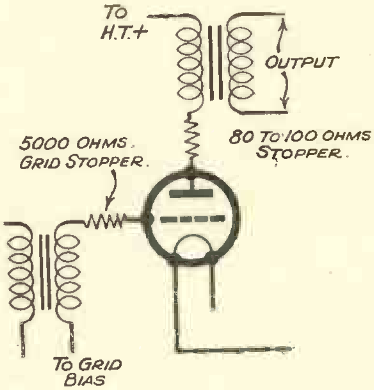


Fig. 11.—GRID AND ANODE H.F. STOPPERS, AS PRECAUTIONS AGAINST H.F. OSCILLATION.

How to Detect the Presence of High-frequency Oscillation

If any of the symptoms mentioned above are noticed the presence of high-frequency oscillation can be confirmed by means of a small tuned exploring coil. A piece of stiff wire should be bent to the form of a loop about 3 inches in diameter, and connected in series with a small flash lamp bulb and a variable condenser of about ·00005 mfd. capacity—an ordinary neutralising condenser will do.

This apparatus, shown diagrammatically in Fig. 10, should be lowered into the amplifier, over the valve connections, taking care not to short-circuit any of the wiring. If oscillation is taking place it will be possible, by adjusting the condenser to tune in the oscillations induced in the exploring coil, when the lamp will light up.

How to Avoid High-frequency Oscillation

Very simple precautions will avoid all risk of parasitic high-frequency oscillations, and these precautions should be included in all amplifiers employing large power output valves. In the first place, a stopper resistance of from 80 to 100 ohms should be included in the anode circuit of the output valve, located as close as possible to the anode terminal. As an additional measure a grid stopper of about 5,000 ohms may be inserted as close as possible to the grid terminal of the valve. The resistances must be non-capacitative—that is to say they must be so designed and positioned that they have small capacity to other portions of the circuit. The resistance in the anode circuit must be wire-wound and capable of carrying continuously the full anode current of the valve.

THE SUPERHETERODYNE

By F. H. HAYNES

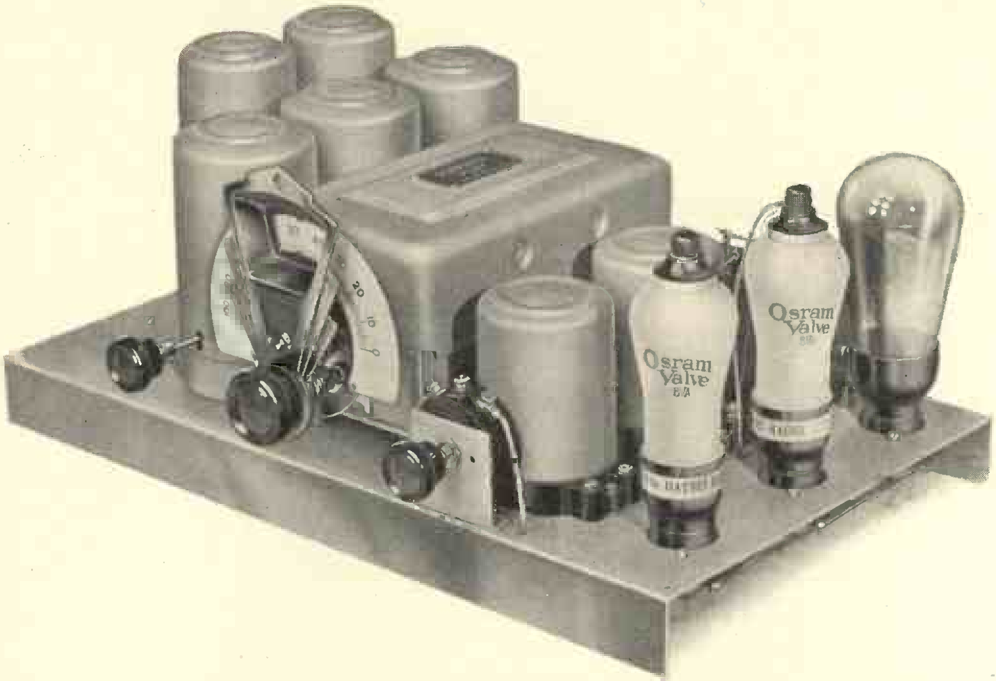


Fig. 1.—A Fine Example of Modern Practice in Superheterodyne Design.
This shows the chassis of the A.C. single dial superheterodyne set, full details of which are given in this article.

CIRCUIT DETAILS EXPLAINED

A WORKING knowledge of the principles of the superheterodyne is an essential if one wishes to remain in the ranks of the radio enthusiasts. It is only necessary to memorise a few facts, and the great field of refinements can be perused with interest. No other circuit principle in radio offers so much scope for development and originality as does the superheterodyne. Entirely on the grounds of the selectivity obtained is this class of receiver popular to-day. Straight H.F. sets can be built to give equal amplification to that of the superheterodynes, but, as the range-getting properties are improved and the number of stations which a set will give increased, need for greater selectivity arises. A straight set may have an input filter designed to exclude stations differing only by small amounts in wavelength to which the set is tuned. Exclusion, however, does not mean extinction, but rather reduction of strength, and high amplification following an aerial filter may restore interfering signals by bringing them up to a value adequate to operate the detector.

Think in Frequencies and not Wavelengths

A very brief statement gives a clue to the working of the superheterodyne, but in making it we must think in terms of frequency rather than wavelength. For the beginner it can be stated that we might have been brought up to express station settings on our tuning dials as frequency instead of wavelength. The frequency of a broadcasting station is given by dividing 300,000,000 by the wavelength. Thus, 200 metres is 1,500,000 cycles, 300 metres is 1,000,000 cycles, and so on. A more convenient unit is the kilocycle, these frequencies then becoming 1,500 and 1,000 kilocycles.

How a Superheterodyne Differs from a Straight Set

Now a superheterodyne only differs from a straight set in that a separate circuit is introduced which generates a frequency slightly displaced from that of the incoming signal. As a result the received signal may be regarded as having been converted to a new frequency, and its value is the difference in frequency between that of the oscillator and the station received. In a simple case a 300-metre station has a frequency of 1,000 kilocycles, and if the oscillator is generating 1,100 kilocycles, then a new frequency must be dealt with, for which our subsequent amplifier and tuned circuits must be designed, and its value is 100 kilocycles. It does not matter if the oscillator is higher or lower in frequency than the incoming signal, the resultant frequency with which the amplifier must deal is simply the difference.

Why a Superheterodyne is so Selective

This simple explanation at once reveals why the superheterodyne is so selective. Selectivity is the amount of steady falling away in the response of a receiver as the frequency departs from that to which it is tuned. Thus a set when tuned to 1,000 kilocycles (300 metres) may render audible a station working on 1,080 kilocycles, which is, of course, a very common state of affairs, the difference of 80 kilocycles being a comparatively small amount in 1,000. On the same basis a receiver tuned to amplify at 100 kilocycles might accept a signal applied at a frequency of 108 kilocycles, or even more.

In the superheterodyne the resultant frequency with which the set has to deal is the difference between the incoming and oscillator frequencies, and a signal which is displaced by as much as 80 kilocycles, as just stated, will give rise to a displacement of the resultant frequency by this amount. The circuits of the set designed to handle the lower resultant frequency, however, say of 100 kilocycles, will give no response to a signal of 180 kilocycles, as would now result. This makes clear the important property of the superheterodyne in that the overall selectivity must not be defined as the selectivity of the circuits which are tuned to pick up the incoming signal, but is entirely governed by the selectivity of the amplifier handling the resultant or, more generally termed, intermediate frequency.

Limitations of Filter Circuits

One often hears reference to filter circuit components as being so selective that they "cut off" at, say, 10 kilocycles off tune. No simple coupled filter of practical utility can achieve such an effect, and everyone appreciates that selective input filters exclude or admit off-tune signals according to their strength. A distant station 10 kilocycles off tune may be adequately cut down by an input filter, but a local station 50 or even 100 kilocycles off tune may still remain at sufficient strength to produce interference.

We have seen how the superheterodyne by its frequency changing oscillator and intermediate amplifier reduces to practical extinction signals which are only a few kilocycles off tune, but there is yet another problem requiring thought. Just as the 1,100 kilocycles oscillator can feed a signal of 100 kilocycles to an intermediate amplifier tuned to this frequency when the incoming signal has a frequency of 1,000 kilocycles, so can it likewise operate in the case of an incoming signal of 1,200 kilocycles. The difference between incoming and oscillator frequency is still the required 100 kilocycles. Our problem is, therefore, of excluding from the set signals which are off tune by an amount of twice the intermediate frequency.

Function of Input Filter in Superheterodynes

A common value of intermediate frequency to-day is 110 kilocycles, and the first tuned circuits of the set must give practically zero response to signals off tune by an amount of 220 kilocycles, or these

Fig. 2.—INPUT FILTER COILS USING INDUCTIVE AND CAPACITY COUPLINGS.

The purpose of this filter is to eliminate second channel interference as evidenced by heterodyning. The S.G. valve with screen removed is the first detector.

Fig. 3.—OSCILLATOR TUNING COIL AND VALVE.

On the left is the small parallel capacity tracking condenser.

will combine with the oscillator frequency and produce an interfering signal. Superheterodynes, therefore, have an input filter similar in type and designed with the same meticulous care as those employed in a straight set. They are not called upon to fulfil the claims so commonly heard as 10-kilocycle cut-off. Their purpose is to exclude signals which are off tune by over 200 kilocycles.

Second Channel Interference

It will thus be seen that without the input filter a superheterodyne will simultaneously receive on two wavebands, these being above and below the oscillator frequency by an amount equal to the frequency of the intermediate amplifier. One of these wavebands, normally the lower, is suppressed by the input filter. Should the filter fail in its purpose, overlapping of stations will result, and the amount of heterodyning between stations be enormously increased. This failing is defined as second channel interference.

Summary of Principles of the Superheterodyne

To summarise up to this point, it might be stated :—

(1) The superheterodyne, in effect, changes the frequency (or wavelength) of the received signal normally to a much lower frequency (longer wavelength), and this is applied to a fixed frequency H.F. amplifier called the intermediate amplifier.

(2) The new frequency or intermediate frequency is the difference between the signal frequency and that of an oscillator.

(3) The oscillator can simultaneously convert stations on two distinct wavebands to the frequency of the intermediate amplifier. This state of affairs, known as second channel interference, is prevented by the use of an input band-pass filter.

(4) The overall selective property of the set, defined as adjacent channel selectivity, is governed by the design of the intermediate frequency amplifier and the selectivity of its circuits.

SUPERHETERODYNE DESIGN

How Single Dial Control is Obtained

The greatest advance made in superheterodyne design is that of single dial control. The problem is much more involved than is the case with a straight H.F. set. In the latter all one needs are coils of equal inductance, condensers of equal capacity at any setting and the provision of trimming condensers so that the unequal stray capacities of each tuned circuit may be equalised. In the superheterodyne the requirements are more complicated. The tuned input circuits forming the band-pass filter are tuned by a pair of condensers on a common shaft, the zero capacities being adjusted by trimming condensers in the customary manner. The circuit of the oscillator, however, is tuned to a different frequency, and at any setting of the single operating control its frequency must differ from that of the filter by an amount equal to the frequency of the intermediate amplifier.

The oscillator frequency may, according to the requirements of the superheterodyne, be above or below the incoming signal frequency, but it is the higher frequency (shorter wavelength) which is adopted. Assuming that the range of the receiver on the medium waves is 1,500 to 500 kilocycles (200–600 metres) and that the intermediate frequency is 110 kilocycles, then the range of the oscillator may be either 1,390 to 390 kilocycles, that is, 110 kilocycles less, or 1,610 to 610 kilocycles, that is, 110 kilocycles more than the frequency of the incoming signal.

Why the Oscillator Tunes to a Higher Frequency than the Input Filter

It is obvious that the lower range of frequency involves a far greater percentage change than does the higher. Moreover, a very much greater change of capacity from minimum to maximum of the tuning condenser is necessary to produce the frequency change demanded on the lower frequency range. The ratio of capacity change that must be provided by the tuning condenser of the oscillator, when passing from minimum to maximum is more than 1 to 12 in respect of an oscillator tuning to a lower frequency than the incoming signal. On the other hand, this ratio is less than 1 to 3 when the higher frequency is used. In all single dial superheterodynes, therefore, the oscillator tunes to a higher frequency (shorter wavelength) than the input filter.

How the Tuning Scale of the Oscillator is made to follow the required Frequency Range

To effect this the oscillator tuning coil is smaller and the tuning range is reduced by limiting the capacity change of the tuning condenser. Assuming that the oscillator tuning condenser is similar to those tuning the input filter, the requirement of reduced capacity change may be met by either putting a fixed condenser in parallel with the tuning condenser, so that it starts at a higher minimum, or by connecting a fixed condenser in series with the variable, so that the maximum value of capacity becomes appreciably reduced. Used alone, either of these alternatives will not maintain the requirement of a constant frequency difference across the tuning range. The one method will make the starting condition right at the bottom end of the scale, and the other will provide the correct condition at the top end of the scale.

Fig. 4.—The Intermediate Amplifier Couplings with Tuning Covers removed.

Four tuned circuits are used, and while being provided with trimmers to compensate for stray capacities only limited adjustment is allowable so that departure from the intended value of intermediate frequency cannot result. The volume control operates simultaneously on the aerial as well as the intermediate amplifier.

Tracking or Padding Condensers

Intermediately across the scale the oscillator will be out of correct ganging whichever method is used, but it is important to note that by one method the oscillator frequency would be too high and the other too low at the intermediate settings. A combination of the two methods can, therefore, be made to produce the required result. Series and parallel capacities are therefore introduced into the oscillator tuned circuit, and these are known as tracking or padding condensers.

Cutting away the Tuning Plates of the Oscillator

An alternative and more obvious method of solving the problem of oscillator ganging is that of cutting away the tuning plates of the oscillator so that the required frequency is obtained at any setting. The objection to this arrangement, particularly as far as the amateur is concerned, is that a special ganged condenser is needed, in which the oscillator plates have been modified in shape on the assumption that a particular set of tuning coils will be used throughout the set and that a given intermediate frequency is to be adopted.

Special Plate Shape does not Meet Requirements on Long Waves

Such a condenser of special plate shape, however, while satisfying the requirements on the medium wave range can only be made to serve on long waves by the introduction of padding condensers. It is

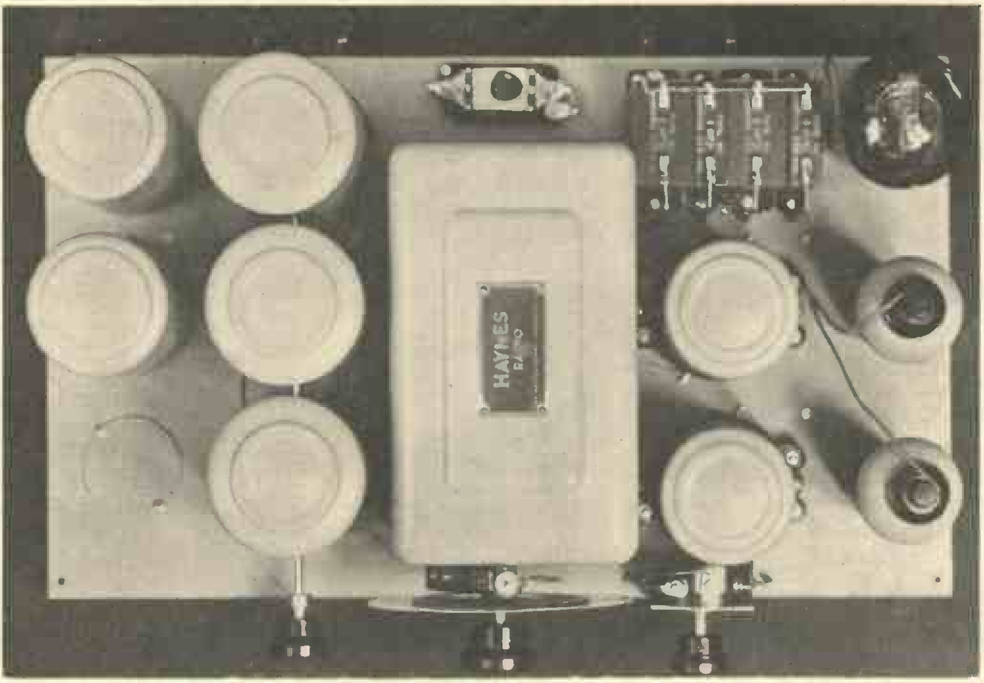


Fig. 5.—GENERAL LAYOUT OF A SUPERHETERODYNE.

Screening must be absolute, to prevent pick-up from a powerful transmitter on the wiring beyond the input filter. The leads on the intermediate amplifier are safe in this respect, as they do not tune to the incoming frequencies.

appreciated, of course, that on the long wave range a change in the values of series and parallel tracking condensers is required, and this is effected in the best designs by associating two auxiliary condensers in the tuning coil itself so that the action of the wave change switch throws an additional condenser in series and another in parallel to restrict further the frequency range into the required limits, starting and finishing the tuning range at the required frequencies.

Maximum Tracking Error

The maximum tracking error has been shown by the manufacture of the special oscillator tuning coil, which achieves the conditions just outlined, to be little more than 1 kilocycle at any position of the dial. Matters are so arranged that this minute error occurs, not at the centre of the tuning scale, but at four points, falling approximately at 0, 30, 75, and 100 on a 100 division tuning scale. In view of the properties of the input filter, these off-tune errors in the oscillator are of not the slightest consequence and are merely stated to show the precision with which the single dial problem has been solved.

VARIATIONS IN SUPERHETERODYNE PRACTICE

Combining Functions of First Detector and Oscillator in a Single Valve

Many variations exist in superheterodyne practice. For instance, the functions of first detector and oscillator may be combined in a single valve, using a screen grid or pentode valve for the purpose. To effect this the tuned oscillator circuit is included in the cathode lead of the valve, assuming it to be of the indirectly heated type, and self-oscillation is produced by coupling this tuned circuit to a

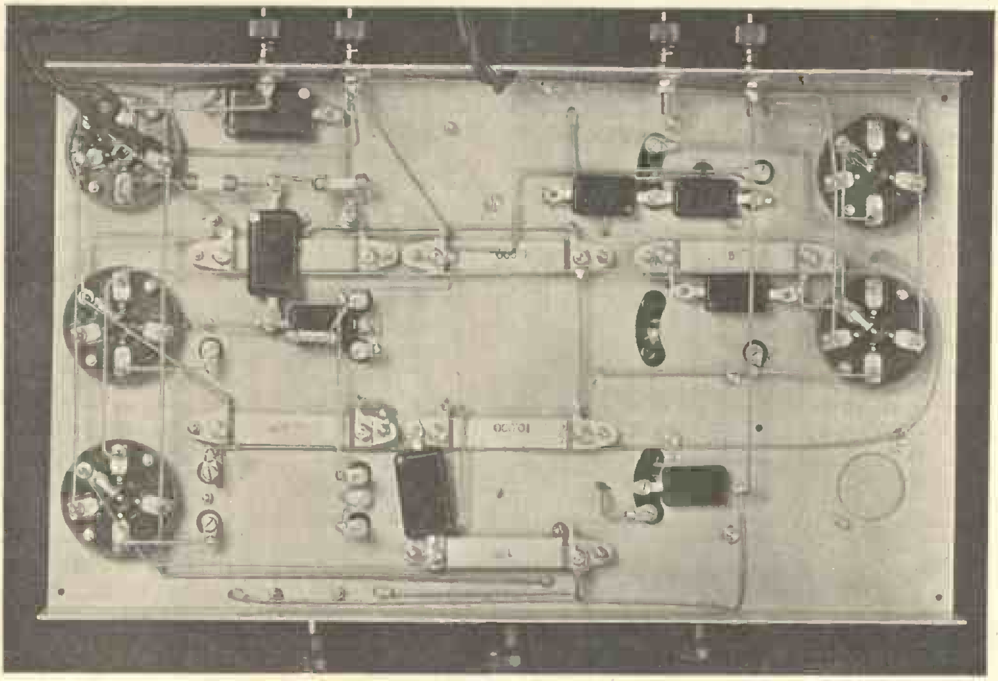


Fig. 6.—UNDERSIDE VIEW OF A MODERN SUPERHETERODYNE.

All wires are totally screened under the metal baseplate. Leads are readily accessible, and the clean layout at once reveals any possible fault or wrong connection.

condenser-fed coil connected to the anode, the primary of the first intermediate coupling serving as a choke coil. Such an arrangement is adopted in many American sets, which tune, of course, only to a single waveband. It is probably preferable and no more expensive to use a separate oscillator valve in the design of sets tuning to long as well as medium waves. It might be mentioned here that the majority of American sets use an intermediate frequency of 175 kilocycles as compared with 110 kilocycles now generally adopted in this country. It will at once be appreciated that the input filter must be far more effective in its purpose in the 110 kilocycle set, and for this reason the American sets with their higher intermediate frequency more easily achieve freedom from second channel interference. Two range sets cannot go to the high intermediate frequency of 175 kilocycles, while a well-designed input filter will prove perfectly successful with 110 kilocycles.

How a Single Range Superheterodyne can be Converted for Long Wave Reception

Some of the single range superheterodynes are readily converted for long wave reception by clipping on an external unit. This consists of a valve arranged as a detector oscillator and tuned without the provision of controls to a fixed frequency. The frequency adopted differs from that of the long wave stations by part of the frequency range of the input filter. In other words, a set becomes a kind of double superheterodyne in which the frequency is changed twice, the input filter being now the intermediate frequency coupling of an additional frequency changer. Instead of tuning the oscillator, however, to a definite number of kilocycles from that of the station required, a fixed frequency oscillator is used, and the normal tuning control changes the frequency of the filter now converted to an I.F. coupling.

Superheterodyne for Ultra Short Wave Work

There are superheterodynes which cover, in addition, the ultra short wave range. Such sets are by no means ideal but represent compromise, and it is obvious that no single intermediate frequency will be satisfactory on all wave ranges.

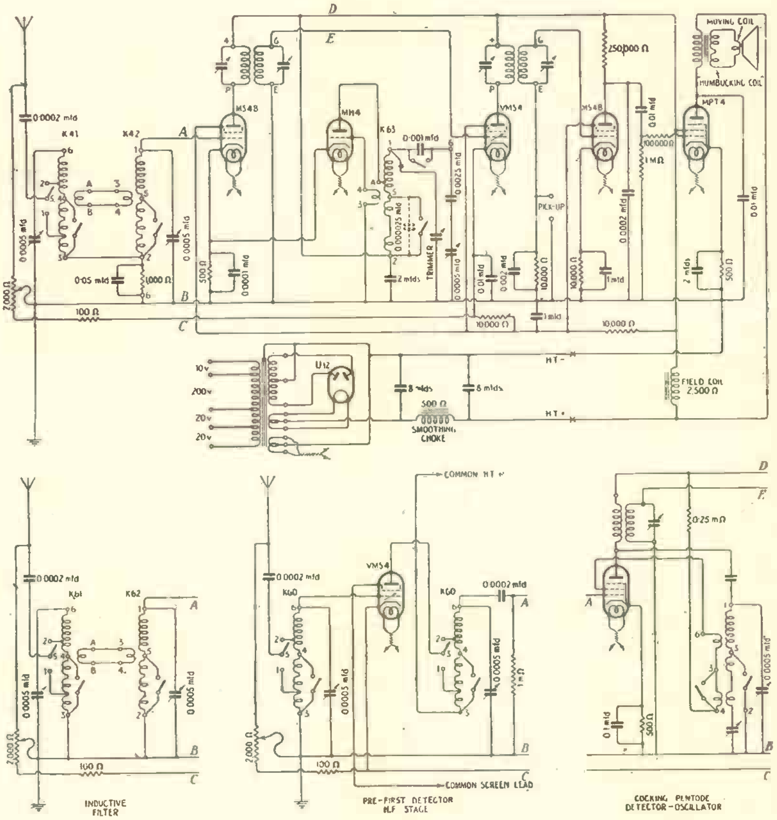


Fig. 7.—Superheterodyne Circuit Embodying the various Principles explained in this Article.

The Autodyne

Short wave receivers must be of the superheterodyne type, and the most satisfactory circuit is probably that of an H.F. amplifier working at signal frequency followed by a single valve acting as detector and oscillator. In this case the detector oscillator has only a single tuned circuit, this being connected to its grid, the anode being coupled back to produce oscillation. This circuit tunes to the oscillator frequency, but in view of the relatively low intermediate frequency employed will accept, at the same time, the off-tune incoming signal. The arrangement is known as the "autodyne," and is to be particularly recommended for short wave reception.

A Point about Input Filter Coupling

To those acquainted with superheterodyne theory a few debatable points of practice may be briefly mentioned. Contrary to accepted ideas, the writer favours mixed inductive and capacity coupling in the input filter. The capacity element in the mixed coupling is alleged to give rise to interference by long wave commercial Morse stations operating on the frequency of the intermediate amplifier. Such interference is not encountered and the mixed filter greatly increases the range-getting properties of the receiver at the maximum end of the tuning scale.

Coupling between First Detector and Oscillator

Coupling between the first detector and the oscillator is best effected across a small condenser of critical value connected in the common cathode leads. A just sufficiently adequate coupling is provided by this method, and as the amplitude from the oscillator falls off with increase of wavelength, so the coupling is automatically tightened by the increasing reactance of the coupling condenser. The first detector functions on the anode bend principle, the incoming signal being a modulated fringe falling on the straight part of the characteristic and superimposed on the steady output from the oscillator.

H.F. Amplifier instead of Input Filter

H.F. amplification at signal frequency preceding the first detector is a simple manner of removing second channel interference, but is no better than a good filter. With aerials limited to a few feet of wire the H.F. stage will increase the range-getting properties, but is of little value with an outside aerial. Its use may mar reception by introducing valve and background noise.

Automatic Volume Control

Intermediate couplings are all band-pass filters, for on the merits of these depend the selective properties of the receiver, and a single intermediate amplifying stage using a variable-mu valve will suffice. The second detector will give distortionless results when working on the anode bend arrangement, in view of the fact that the modulation is very light and should fall on a reasonably straight part of the characteristic. This form of detection can be readily arranged to provide some desirable measure of automatic volume control while the values used for the subsequent L.F. intervalve coupling take into account the requirements of tone correction.

DESIGN FOR A TYPICAL A.C. SINGLE DIAL SUPERHETERODYNE

This is a single dial control superheterodyne tuning to both medium and long waves and making use of tracking condensers on both ranges.

Materials Required

1 Baseplate. Set.
1 Baseplate. Eliminator.
5 5-Pin valve holders, with recessed underside terminals (*W.B.*).
1 4-Pin valve holder (*W.B.*).
1 3 Section tuning condenser with cover, dial light, bracket and geared scale (*British Radiophone*).
1 Set of coils, mixed filter. Types K41, K42, K63 (*Colvern*) ; for inductive filter Types K61, K62, K63 (*Colvern*) ; for H.F. stage Types KGO, KGO, K63 (*Colvern*).
1 Volume control potentiometer, 2,000 ohms Type ST5C (*Colvern*).
2 Intermediate couplings 110 K.C. (*Colverdynes*).
2 Condensers 2 mfd., 250 volts D.C. working *T.C.C. Type* 65.
2 Condensers 1 mfd., 250 volts D.C. working *T.C.C. Type* 65.
2 Valve screens without anode holes, Type VSC (*Colvern*).
1 Set of Bakelite shrouded terminals (*Belling-Lee*).
1 Packet terminal washers (*Belling-Lee*).
1 Oscillator trimming condenser (*Colvern*).
3 Resistances, half watt type, 100,000 ohms, 250,000 ohms, 1 megohm (*Dubilier*).
6 Resistances, strip type, 3/10,000 ohms, 2/500 ohms, 1/100 ohms (*Colvern*).
8 Condensers, 3/0·01 mfd., 1/0·0025 mfd., 1/0·001 mfd., 2/0·0002 mfd., 1/0·0001 mfd. *T.C.C. Type* " *M*."
1 Coil switch rod adaptor sleeve.
Matched knobs—1 large, 2 small.
1 Mains transformer, Type 47 (*Rich and Bundy*).
1 Smoothing choke, Type E103 (*Rich and Bundy*).
2 Electrolytic condensers 8 mfd., 450 volts working (*Dubilier*).
1 Loud Speaker with pentode output transformer, 2,500 ohm field (*Rola*).
1 Packet screws.
Solder tags.
Special flux cored solder.
Wire No. 20 S.W.G.
8 Lengths 1 mm. silk sleeving.
1 Length 2 mm. silk sleeving.
1 Full scale blue print.
6 Valves, 2/MS4B, 1/VMS4, 1/MH4, 1/MPT4, 1/U12. If H.F. stage is required, 1 additional VMS 4 (*Osram*).

For gramophone reproduction add :—
1 Condenser 0·002 mfd., Type " M " (*T.C.C.*).

1 Resistance half watt type, 10,000 ohms (*Dubilier*).

Gramophone motor Type 202A (*Garrard*).

Pick-up (*British Radiophone*).

Pick-up volume control 25,000 ohms Type ST5C with special knob (*Colvern*).

The complete Kit is obtainable from Haynes Radio, 57, Hatton Garden, London, E.C. 1.

Practical Features and Constructional Hints

The method of wiring can be seen from the photographs and from the theoretical circuit in Fig. 7. Before fixing the valve holders see that the terminal screws are tight and look for whiskers of metal in the screwheads which might possibly contact with the plates. Likewise, tighten up the terminals on the resistances before fitting. See that the screws holding the tuning condenser duly contact with the plate.

Very little scraping of the cellulose is required, for, unlike hard paint, the screws readily bite through the cellulose surface. Lightly scrape the plate under the earthing tags of the Colverdyne intermediates as well as under the earth terminal washer and the electrolytic condensers of the eliminator.

Fixing the Condensers

The washers on the electrolytic condensers go under the plate. The two 0·01 mfd. condensers located near the output valve are suitably elevated by using additional nuts. A step shaped bend is made in the tag of the 0·0002 mfd. condenser where it is held under the nut fixing one of the intermediates, so that its other tag becomes adequately elevated.

The Volume Control Potentiometer

In fixing the volume control potentiometer, drop the screws through the holes first, having previously set the thus obscured trigger on the intermediate to its centre position. A tag with wire attached is held under the head of one of the screws and is subsequently connected to the centre terminal of the potentiometer. When earthing tags or additional components are carried by any of the component holding down screws make use of an extra nut for the purpose. Note that the coil cams clamp down on to the face of the baseplate, and that the flat nuts do not intervene.

Check the Wiring

It is worth while carefully checking over all wiring before bringing the set into operation. Experience reveals that faults in wiring are comparatively rare, and in view of the fact that the valves supplied are specially tested it is unlikely that trouble will be encountered. The first detector is metallised, and whether or not the oscillator is also metallised it must, like the detector, be fitted with a screening cover. The pair of screening covers prevent local station pick-up, against which the metallising connected to the cathodes affords no protection.

Points about the Coils

The coils on the front intermediate are spaced so that ½ inch is left free at the top of the pillar. In the rear intermediate the coil faces should be adjusted to be ¼ inch apart. The normal setting of the oscillator trimmer is 1¼ turns away from the down tight position.

Adjusting the Band-pass Trimmers

The front pair of band-pass trimmers are slowly pushed round with the end of a pencil to give maximum signal. A little time spent on the trimming soon reveals the best settings. With the front lever of the intermediate couplings set in the central position the remaining three are pushed over to give the best results when listening to a distant station.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION IV—CONDENSERS AND CAPACITY

THERE are two main types of condensers used in all classes of electrical and radio work, viz., fixed condensers and variable condensers, and several subdivisions of type according to design, structure, size, function, and so on. We shall discuss first the different forms of variable condensers used in radio reception for both tuning and reaction circuits.

What comprises a Tuned Circuit

It is well known that a combination of a coil and a condenser forms a TUNED CIRCUIT—*i.e.*, a circuit which, when connected in a receiver, or to an aerial, is capable of selecting a wireless signal of any *given* wavelength or frequency from a number of signals of different wavelengths or frequencies. In a later article we shall discuss tuned circuits in more detail. It will suffice now if we accept this characteristic of the coil and condenser combination as an established fact.

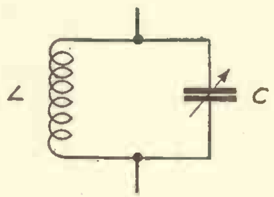


Fig. 1.—A TYPICAL TUNING CIRCUIT.

Consisting of an inductance L, and variable condenser, or capacity, C, joined in parallel.

Two Ways of Varying the Tuning

In the case of a radio receiver, it is necessary to be able to vary the tuning so that signals of different wavelengths or frequencies may be received. This can be accomplished in one of two ways, by varying either the value of the inductance, or the CAPACITY of the condenser, comprising the tuned circuit. The latter course is generally the simpler, and is the course nearly always adopted.

A Typical Tuning Circuit

Fig. 1 shows a typical tuning circuit consisting of an inductance L and a variable condenser, or capacity, C, joined in parallel. The symbol at C is in general use for representing a capacity in a circuit diagram, and the arrow indicates a variable capacity. C is the mathematical shorthand for capacity, just as L is used for inductance. (Strictly speaking, the term "capacity" bears the same relation to a condenser as the term "induction" bears to a coil, and the term corresponding to "inductance" is "capacitance." This term has dropped out of use, however, and the term "capacity" is now generally used wherever "capacitance" is intended.)

Let us suppose that this circuit is connected in a receiver. As the capacity of C is increased—*i.e.*, as the vanes forming the condenser are interleaved—the wavelength to which the circuit responds is increased. *Thus, the longer the wavelength of the signal we wish to receive, the more capacity we must use in the tuning circuit.*

How Capacity of a Condenser can be Calculated

Now the capacity of a condenser can be calculated, and depends on such factors as the area of overlap of the two sets of vanes, the number of vanes, the distance between them, and so on. Capacity is measured in microfarads (abbreviated as mfd.), and micro-microfarads (m.mfd.). A microfarad is $\frac{1}{1000000}$th part of a farad, which is the unit of capacity, and a micro-microfarad is $\frac{1}{1000000}$th part of a microfarad. Expressing these relations in the forms of equations, we have :—

10^6 mfd. = 1 farad, and
10^6 m.mfd. = 1 mfd.

The usual size of variable condensers ranges from about ·001 mfd. to about ·000005 mfd., *i.e.*, from 1,000 m.mfd. to 5 m.mfd. A condenser of a size larger than 10 or 20 mfd. is very rarely met, and would be unwieldy in its physical dimensions, except in the case of a certain type of condenser known as an ELECTROLYTIC condenser, of which type a size of 1,000 or 2,000 mfd. is frequently used.

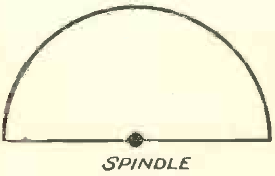


Fig. 2A.—EARLIEST TYPE OF CONDENSER VANE.

With semi-circular-shaped moving vanes.

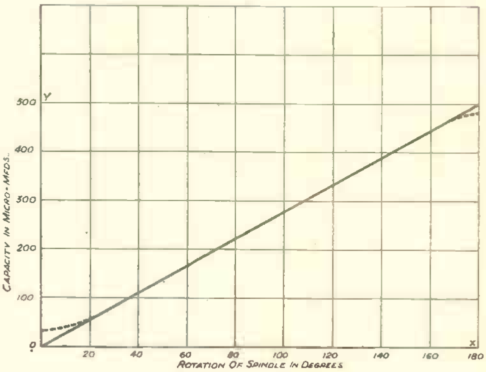


Fig. 2B.—GRAPH SHOWING CAPACITY OF CONDENSER WITH VANES AS IN FIG. 2A.

Formula for Determining Capacity of a Condenser

The formula for determining the capacity of a condenser is :—

Capacity = 1·111 × 10^{-6} × (the number of spaces between the two sets of vanes) × (the area of overlap) ÷ (4π × the distance between the vanes)—

i.e., $C = 1{\cdot}111 \times 10^{-6} \times n \times A \div (4\pi d)$ microfarads,

$$\textit{i.e.},\ C = 1{\cdot}111 \times 10^{-6} \times \frac{nA}{4\pi d} \text{ mfd.} \quad (1)$$

$$\text{or}\quad C = 8{\cdot}85 \times 10^{-8} \times \frac{nA}{d} \text{ mfd.} \quad (1A)$$

In the formula all the measurements are in the metric system—*i.e.*, the area A is measured in square centimetres and the distance d in centimetres. Equations (1) and (1A) only apply to the particular case of a condenser with an air gap between the two sets of vanes.

Specific Inductive Capacity

When some other material is used, such as bakelite or mica, the formula becomes :

$$C = 1{\cdot}111 \times 10^{-6} \times \frac{nkA}{4\pi d} \text{ mfd.} \quad (2)$$

$$\text{or } C = 8{\cdot}85 \times 10^{-8} \times \frac{nkA}{d} \text{ mfd.} \quad (2A)$$

where k is a number which depends on the particular insulating material used between the vanes. The material is called a DIELECTRIC material, and the number k is its SPECIFIC INDUCTIVE CAPACITY or S.I.C. The table below gives the value of k for different substances which are commonly employed as dielectrics.

It will be seen that, for air, $k = 1$, and putting this value for k in equation (2) we obtain equation (1), which is the special case for air dielectric. The number k is actually the ratio of the capacity of a condenser when the dielectric material is employed to the capacity when the material is removed and the dielectric is air. Thus we see that if we take a variable condenser with air dielectric and capacity of ·0005 mfd. and employ sheets of solid paraffin wax as dielectric, the capacity will be increased to ·0005 × 2·0, *i.e.*, to ·001 mfd. Where a range of values is

Material.	S.I.C. (k).
Air	1·0
Ebonite	2·0 to 2·5
Flint glass	7·0 to 10·0
Gutta percha	2·5
Insulating oil	2·0 to 3·0
Mica	5·0
Paper	1·8 to 2·5
Paraffin (solid)	2·0
Plate glass	6·0 to 8·0
Porcelain	4·0 to 6·0
Resin	1·7
Shellac	3·0 to 3·5
Sulphur	2·6
Turpentine	2·1 to 2·3

given for k in the above table the actual value depends on the quality and purity of the material employed.

Factors which Govern Distribution of Stations Round Tuning Dial

The rate at which the wavelength of the circuit of Fig. 1 increases will depend entirely on the rate at which the capacity of C increases as the tuning dial is rotated. From the point of view of satisfactory reception of broadcasting stations, it is necessary that the capacity shall increase at such a rate that the stations are evenly distributed around the tuning dial. This is the ideal case. In practice, the distribution of stations around the dial depends on two factors, (1) the wavelength and frequency differences of the stations concerned, and (2) the shape of the moving vanes of the tuning condenser. The shape of the fixed vanes is, in general, quite unimportant, provided that they are large enough to completely overlap the moving vanes when interleaved.

Straight Line Capacity Condenser

In the early days of broadcast reception, variable condensers had semi-circular-shaped moving vanes, as shown in Fig. 2A. If we draw a graph showing the *capacity* of such a condenser at each dial reading we shall obtain the straight line of Fig. 2B. It will be seen that the scales used for both axes are equi-spaced scales. In actual practice the graph is not quite a straight line, but curves slightly at each end of the dial reading, as shown by the dotted lines. This type of condenser is still widely employed for reaction circuits, but it is of very little use for tuning circuits, since it crowds the stations together in the first few degrees of rotation.

The name STRAIGHT LINE CAPACITY is sometimes given to this type of condenser to describe the fact that the graph showing the relation between capacity and rotation of spindle is a straight line.

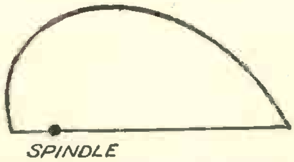


Fig. 3A.—THE STRAIGHT LINE WAVELENGTH CONDENSER VANE.

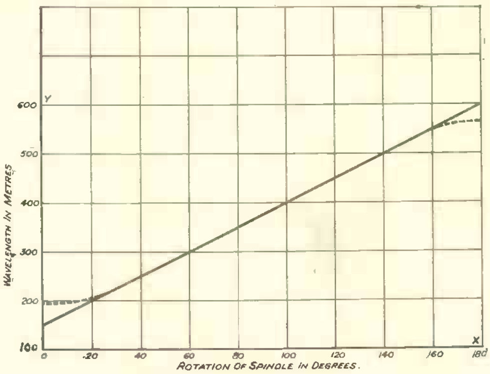


Fig. 3B.—GRAPH SHOWING CAPACITY OF CONDENSER WITH VANES AS SHOWN IN FIG. 3A.

Square Law or Straight Line Wavelength Condenser

A form of condenser which found very great favour a year or two ago is the SQUARE LAW, OR STRAIGHT LINE WAVELENGTH, condenser. The usual shape of the moving vanes is shown in Fig. 3A, and it is clear that as the condenser is rotated the area of overlap of the vanes is small at first and greater towards the end of the rotation.

If we employ a condenser of this type in the circuit of Fig. 1 and measure the *wavelength* to which the circuit

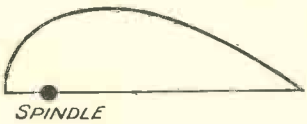


Fig. 4A.—THE STRAIGHT LINE FREQUENCY CONDENSER VANE.

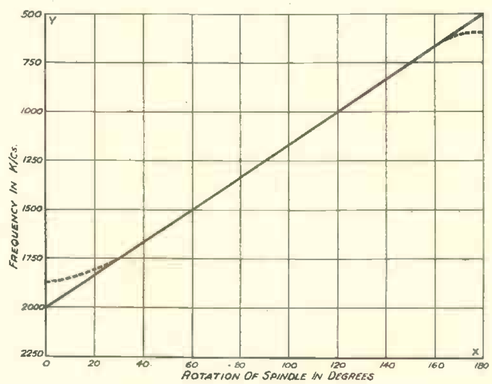


Fig. 4B.—GRAPH SHOWING FREQUENCY TO WHICH CIRCUIT IS TUNED WHEN USING VANES AS SHOWN IN FIG. 4A.

is tuned at different dial readings, we shall obtain a series of readings which, plotted on a graph, will give the straight line of Fig. 3B). As before, this is the ideal case, and in practice the line curves at each end of the tuning range, as indicated. The effect of this slight curvature is to limit the wavelength range of the circuit.

Straight Line Frequency Condenser

The STRAIGHT LINE FREQUENCY condenser is probably the most widely used type of condenser in most modern receivers. The usual shape of the vanes is shown in Fig. 4A, and Fig. 4B is the graph showing the *frequency* to which the circuit is tuned at each position of the dial. The practical case departs from the ideal as shown by the dotted lines.

Log Law or Log Line Condenser

There is one other type of condenser which is especially suited for use in circuits which are ganged to one tuning control. The shape of the moving vanes is similar to that of the square law condenser. It is known as the LOG LAW or LOG LINE condenser, and in this case the graph showing the *logarithm of the capacity* against the dial reading is a straight line, as shown in Fig. 5. A logarithmic scale is used for the axis OY, and the values of C are measured along it. This is equivalent to measuring the values of log C along an equi-spaced scale.

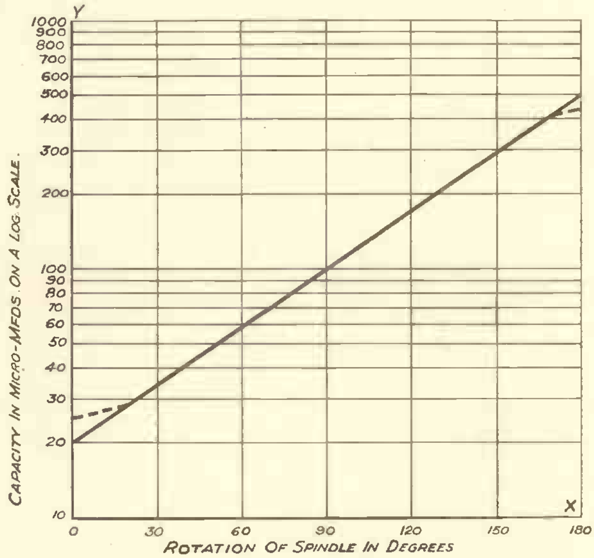


Fig. 5.—GRAPH SHOWING DIAL READING AGAINST THE LOGARITHMIC OF THE CAPACITY, WITH A LOG LAW OR LOG LINE CONDENSER.

Comparison of the Main Types

For easy comparison of the main types, Fig. 6 shows the three shapes of vanes superposed. The relative sizes of the vanes have been maintained, and the lines joining O to P, Q, R, S, T, U, and V are equi-spaced at 30 degrees. As the vanes are interleaved with the fixed vanes in the direction indicated by the arrow, the area of overlap varies widely for the three types. In the case of the straight line frequency type, in particular, approximately one-half of the total area is enmeshed at the last 30 degrees of rotation, whereas the straight line capacity type enmeshes equal areas for equal amounts of rotation.

Why Straight Line Frequency is most Suitable

We must now consider why the straight line frequency condenser has found great favour with designers of modern receivers. It is well known that broadcasting stations are now separated by frequencies and not by wavelengths. A 9 kc/s. separation —*i.e.*, a frequency difference of 9 kc/s. between each station—is generally accepted as a satisfactory separation under the present crowded conditions of the ether in Europe. There are many arguments in favour of a 12-kc/s. separation, but this is quite impossible while there are so many stations distributed throughout the various European countries. The wavelength range from 200 metres to 600 metres is equivalent to a frequency range from 1,500 kc/s. to 500 kc/s., *i.e.*, a range of 1,000 kc/s. With a separation of 9 kc/s., there is room for some 111 stations in this range. Reference to the latest list of broadcasting stations in Europe shows that there are more than 180 stations, and the result of this congestion is very bad inter-station interference.

According to the official list of frequencies, the more powerful—and hence more easily received—stations are evenly distributed over this frequency range. Hence, in place of the frequency gradations along the axis OY of Fig. 4B we could have written the names of these stations as in Fig. 7. It will be seen from this graph that the stations are evenly spaced around the tuning scale. The other types of condenser cause the stations to be more crowded towards the lower end of the scale. It will be clear, of course, that, in the case of the log law condenser, considerations of ganging outweigh the fact that slightly uneven station distribution is obtained with this condenser.

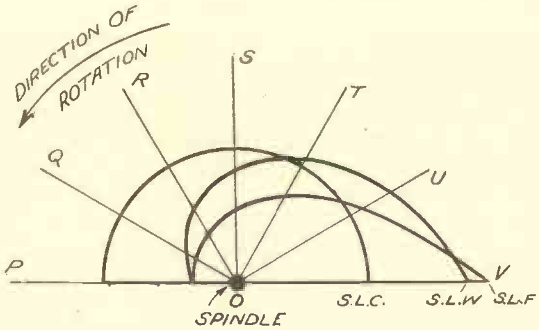


Fig. 6.—This shows the Three Main Types of Condenser Vanes superimposed for Easy comparison.

The Differential Condenser

The differential condenser is another type of variable condenser used for reaction control. It consists of two straight line capacity condensers combined into one condenser. (See Fig. 8.) The maximum capacity of the condenser can exist between either the moving vanes and fixed vanes 1, or between the moving vanes and fixed vanes 2, and *in all positions* the total capacity is approximately the same, and equal to the maximum capacity. As the capacity is increased on one side it is decreased on the other side at the same rate. Thus the capacity of this condenser is only variable in as far as the distribution of the capacity between the two sides is concerned, the total capacity remaining constant. This device enables a small defect in reaction circuits to be remedied, and we shall deal with this in a later article.

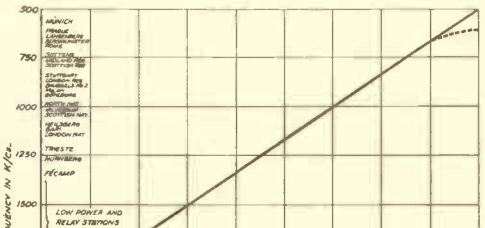


Fig. 7.—Showing how the Stations are evenly Spaced around the Tuning Scale when using a Straight Line Frequency Condenser.

How to Determine the Capacity of a Condenser

In order to find the capacity of a condenser by means of the formulæ in equations (1) and (2), we need to know the area of overlap of the two sets of vanes. In the case of square law, straight line frequency, and log law types, it is not easy to calculate the area of the vanes. In most cases the maximum capacity of a condenser is marked on one of its end-plates, but there are occasions when it is necessary to know the maximum capacity of a condenser which is not so marked. To do this all that is needed is a sheet of graph paper marked in squares of side 1 cm. Each large square, of area 1 sq. cm., will probably be divided into twenty-five small squares, each of area $\frac{1}{25}$th sq. cm. Cut out a piece of paper the *exact* shape of one of the moving vanes. In most cases the portion of the moving vane near to the spindle does not overlap the fixed vanes, hence cut out a shape around the spindle so that the final shape of the paper (see Fig. 9) is the exact shape of the area of the moving vanes which overlaps in the maximum capacity position. Count the number of *complete* small squares on the paper, and also the number of fractions of a small square, whether they are smaller or larger than a half square. Divide the latter number by two, and add the result to the former number. Divide the new number by twenty-five, and the result is approximately the area of overlap (A) in square centimetres required for the formula—

i.e., if S = the number of complete small squares, and
F = the number of fractions of a small square,

$$\text{then} \quad \text{Area} = \left(S + \frac{F}{2}\right) \div 25 \text{ sq. cm.}$$

Note.—If there are 100 small squares in each square centimetre, the area is obtained by dividing by 100, and not by twenty-five.

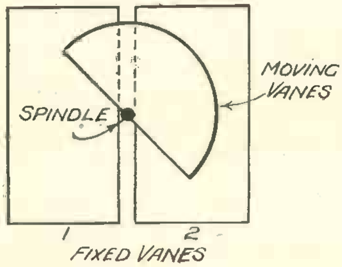


Fig. 8.—Plan of Vanes of a Differential Condenser.

Fixed Condensers

The fixed condensers used in radio work almost invariably employ some form of solid dielectric so that the capacity of the condenser can be as large as possible for a given physical size. The spacing between vanes is also extremely small, being of the order of a few thousandths of an inch. (*Note.*—The engineer uses the term MIL in referring to small distances of this order. 1 mil = $\frac{1}{1000}$ inch. Thus the distance between the plates of a fixed condenser is of the order of a few mils only.)

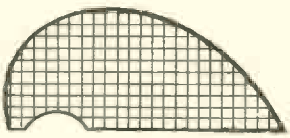


Fig. 9.—Showing how the Capacity of a Condenser can be Calculated.

Calculating the capacity of fixed condensers is seldom necessary, as it is impossible to measure area of overlap, the distance between plates, and so on, without first ruining the condenser by taking it to pieces. The more important features of a fixed condenser are :—

(1) It must be highly efficient, particularly when used in the input, or radio frequency, stages of a receiver.

(2) It must withstand the voltages applied to it without breaking down, and thus causing a short circuit.

(3) Its capacity must remain constant during operation under all normal working conditions.

Materials of which Fixed Condensers are made

Generally speaking, copper foil and mica dielectric type condensers are the most efficient of the solid dielectric fixed condensers, but this type is not available in sizes larger than about ·1 mfd. due to increased production costs for larger sizes. For capacities bigger than this the condenser is usually made of metal foil and waxed paper dielectric, these materials being in strips and wound together. The condenser is thus built up in a roll which can be compressed into a small space. In this type, sizes up to 8 mfd. are quite common. The electrolytic condenser, to which we have already referred, consists of a metal plate in a chemical solution. The second electrode, or plate, is the metal container holding the solution. These condensers are only for use in D.C. circuits, and are available up to about 2,000 mfd.

VARIABLE CONDENSERS

By FRANK PRESTON, F.R.A.

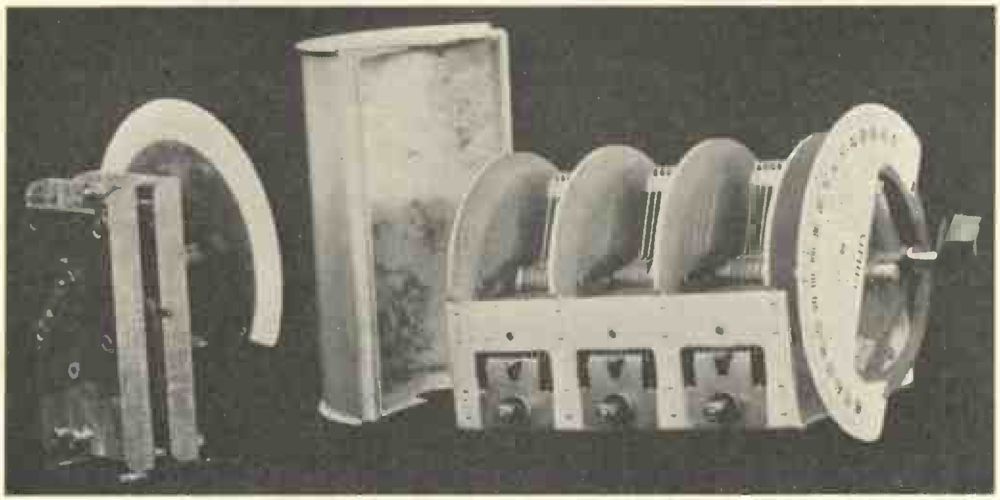


Fig. 1.—Two ·0005 mfd. Three-gang Condensers.

Showing how the physical size of condensers is altered by different dielectrics. That on the left has bakelite dielectric, while that on the right has a dielectric of air.

THE extremely wide range of variable condensers on the market makes the choice of any particular instrument rather difficult. But as the condenser will in nearly every instance have not a little influence on the efficiency and ease of operation of the set in which it will be used it is well to consider in some detail the available types.

Air or Solid Dielectric

Most variable condensers have an air dielectric, or in other words, the vanes are separated by air only, but there are a few in which the dielectric consists of mica, bakelite or other insulating material. The former are always more efficient because air is the most perfect dielectric material known, causing the very minimum waste of energy. On the other hand, the solid dielectrics, although having lower efficiencies, have what is known as a higher "dielectric constant," which means that a smaller area of electrodes (vanes) is required to make a condenser of any given capacity. In addition, the vanes can be placed much nearer together without there being the least fear of causing a short circuit. And the nearer together the vanes are placed the greater the capacity for any particular electrode area. In consequence, the physical size of a condenser with solid dielectric is enormously less than that of an air dielectric condenser of equal capacity.

This point is demonstrated in a striking manner in Fig. 1, which shows two ·0005 mfd. three-gang condensers of the same make. That on the left consists of three bakelite dielectric condensers, and that on the right of air dielectric ones.

Another disadvantage of solid dielectric condensers is that their "all out," or minimum capacity, is comparatively high; this point will come up for consideration later on.

Solid Dielectric Unsuitable for Tuning Condensers

It will be clear from the above brief explanation that, generally speaking, it is unwise to employ a solid dielectric variable condenser for the tuning circuit of any set in which a high degree of sensitivity is required. Such a condenser is nevertheless very useful for tuning a set of the portable type where space and weight are important considerations, and where maximum efficiency is frequently a matter of compromise.

Reaction Control

A solid dielectric condenser is also very useful for reaction control for, being virtually in shunt with the high tension voltage, insulation is a matter of great importance. Besides, condenser efficiency is of little consequence in this part of the circuit, because any loss can be restored by increasing the strength of reaction coupling ; this means that a slightly higher condenser setting will be required to produce oscillation. A low minimum capacity is not necessary in a reaction condenser because a certain amount of capacity is always required to be in circuit.

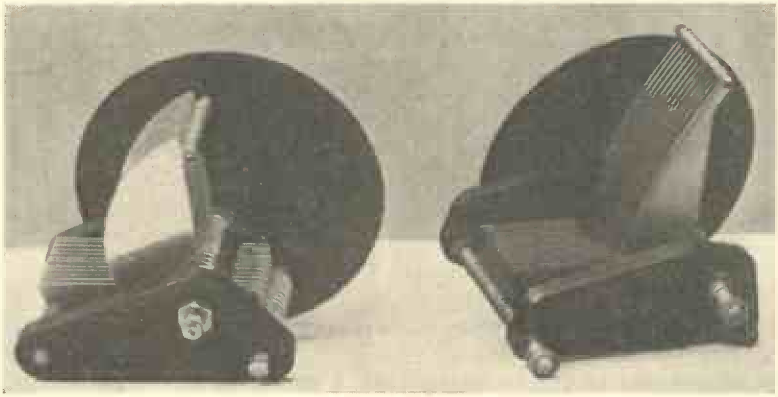


Fig. 2.—Two Types of Variable Condensers.

On the left is a " log " condenser, and on the right a " straight line frequency " condenser.

Four Types of Condensers

There are four general types of variable condensers, which are known as straight-line capacity, square law, straight-line frequency and logarithmic. The names vary with the shape of the vanes, and each type has special advantages for certain conditions and requirements. Let us consider them separately.

Straight-line Capacity

Condensers of this type have semicircular vanes, like those of the condenser shown on the left in Fig. 6. As a result, the capacity increases at a uniform rate as the moving vanes are turned through half a revolution. Thus, if a graph were made by plotting the capacity of the condenser at various settings against the corresponding dial readings, a straight line would result; hence the name straight-line capacity.

The straight-line capacity condenser is quite suitable for reaction control, but is unsatisfactory for tuning purposes, because the wavelengths to which a coil will tune are not proportional to the capacity of the tuning condenser. As a result, when using a condenser of this type, stations which come in towards the bottom of the tuning range are crowded together, whilst those at the upper end are spaced unnecessarily.

Square Law

The last-mentioned fact explains the reason for the introduction of square law or straight-line wavelength condensers. The capacity of these latter is not proportional to the dial reading, but follows an entirely different " law." The shape of the vanes is so arranged that the wavelength of the tuned circuit is proportional to the dial reading. Thus a straight-line graph would result if wavelengths were plotted against corresponding dial readings.

This is very useful from the point of view of receiver calibration, but is not by any means ideal, because it still causes stations on the lower wavelengths to be more crowded than those on the higher ones. On first thoughts the latter statement would appear to be incorrect, but we must bear in mind the fact that wavelength (in metres) does not give a true indication of station separation. To explain this point it is necessary to think in terms of frequency, which varies in inverse proportion to wavelength.

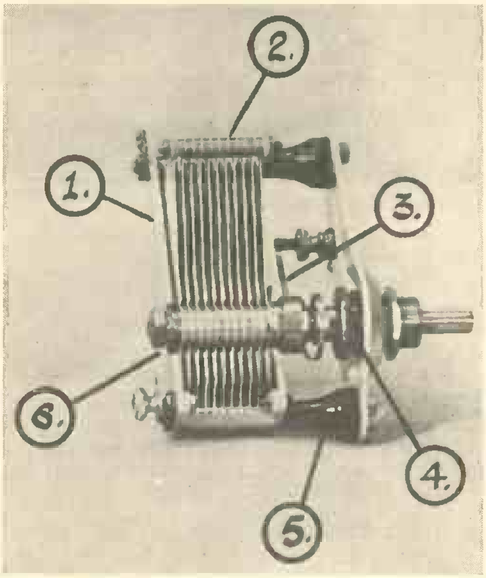


Fig. 3.—IMPORTANT FEATURES OF A CONDENSER.

1, Rigid end plate; 2, moving vanes braced together; 3, flat spring pigtail soldered to terminal; 4, ball-bearing bush; 5, all solid dielectric outside electrostatic field; 6, absence of lower spindle bush.

An Example

Thus, let us take an example. Kaiserlautern transmits on a wavelength of 560 metres, which is equivalent to a frequency of 536 kilocycles, and Budapest uses a wavelength of 550 metres, or a frequency of 545 kilocycles. The wavelength separation of these two stations is 10 metres, and the frequency separation 9 kilocycles.

Now let us compare these figures with those of two stations lower down the scale. Brussels transmits on 216 metres, or 1,391 kilocycles, and Warsaw on 214·2 metres, or 1,400 kilocycles. In this case the frequency separation is still 9 kilocycles, but is equal to only 1·8 metres.

From the above it will be seen that although both pairs of stations are equally separated (according to frequency), the spacing between the former ones would be more than five times as great as that between the latter, on the dial of a square-law condenser.

Straight-line Frequency

We can now appreciate the value of the straight-line frequency condenser, which is so designed that the frequency of the tuned circuit varies in definite proportion to the dial rotation. Thus any stations of say, 9 kilocycles separation (this is the separation allowed between all high-power European transmitters) would be the same number of degrees apart on the tuning dial, whatever their wavelengths.

For many purposes, then, the straight-line frequency condenser is by far the most convenient since it gives equal station separation over the whole of its scale, and also permits of easy calibration, provided the latter is carried out in frequencies, and not in wavelengths.

Not Suitable for Ganging

This type of condenser is about the most unsuitable one for ganging, because of its comparatively small capacity at low dial readings. In consequence of the latter, stray capacities and "trimming" capacities absolutely ruin the matching on all except the higher dial readings.

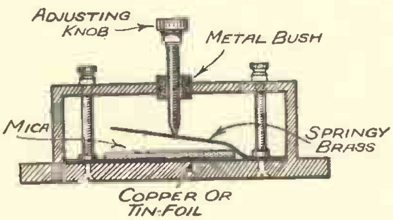


Fig. 4.—DETAILS OF A PRE-SET OR TRIMMER CONDENSER.

Log Condensers

Log law, or logarithmic condensers, are the best for ganging purposes, and their tuning characteristics lie somewhere between those of the square-law and straight-line frequency types. Actually, the dial reading is proportional to the logarithm of the capacity. In other words, a straight-line graph would be produced by plotting the dial readings against the logarithms of the corresponding capacities.

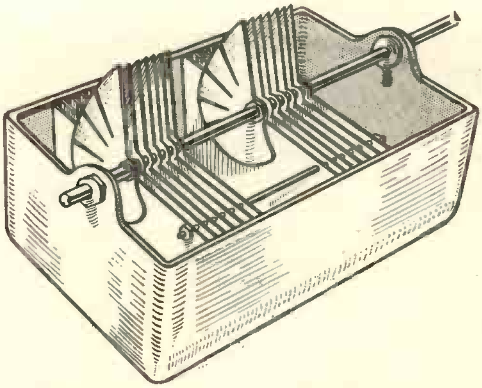


Fig. 5.—A Split Endplate Condenser.
The end moving vane of each section is split. The capacity of any condenser section can be adjusted at any part of the dial by pressing the appropriate sector of the split vane towards the adjacent fixed ones.

Desirable Features

The efficiency of a variable condenser depends not only upon the dielectric material, but also on a number of other features, some of which are depicted in Fig. 3. There are so many important constructional details that it is difficult to arrange them in order of importance, but perhaps one should first mention mechanical rigidity.

Structure should be Rigid

A rigid structure is very desirable, because there is then less fear of the moving and fixed vanes touching. In addition to this, however, a condenser of flimsy build is always troublesome, because it is impossible to calibrate it with any degree of accuracy.

Mounting the Spindle

A sound method of mounting the spindle is the next consideration, and here a cone and ball bearing is generally preferable to all other methods. Some tensioning device for regulating the friction between the spindle and framework is also desirable for this makes it possible to compensate for any wear which might take place, and enables one to regulate the stiffness to suit personal requirements.

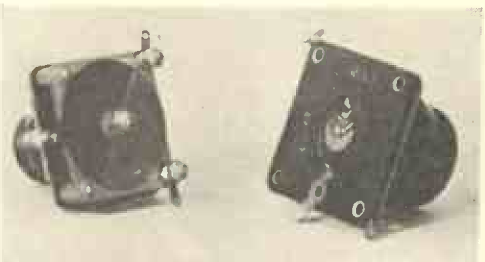


Fig. 6.—Two Differential Condensers.
That on the left is of the "straight line capacity" type, having semi-circular vanes.

Using a "Pigtail"

The method of making connection between the moving vanes and corresponding terminal is important, and provided it is of suitable material, a "pigtail" undoubtedly gives the most reliable contact. The pigtail should consist of either braided wire or a flat spring, to ensure that no breakage can occur.

"Electrical" Requirements

The principal requirement from the electrical point of view is that all solid dielectric should be avoided so far as possible. A certain amount *must* be used to insulate the spindle, but this should be kept outside the electro-static field, as shown in Fig. 3. To fulfil this requirement it is necessary to dispense with a lower-spindle mounting bush; this makes it doubly essential to use a really sound mounting at the upper end.

Connection between individual plates of the same group should be perfect; some manufacturers solder the plates together to ensure contact.

How to Prevent Self-oscillation

All moving vanes should be of stout-gauge material (brass or aluminium is equally good), and should be firmly clamped together to prevent vibration. The latter point is most important when the speaker and receiver are housed in the same cabinet, because the speaker sets up a good deal of vibration, which is liable to affect the vanes. And if the vanes do vibrate in sympathy (especially if the set is of a sensitive, accurately tuned type) a form of self-oscillation will be provoked.

Ratio between Maximum and Minimum Capacity

The minimum capacity should be as low as possible for any given maximum, or in other words the ratio between maximum and minimum capacity should be as high as possible. The greater this ratio is, the greater is the frequency range that can be covered with any one coil. A good ·0005 mfd. condenser should have a minimum capacity of no more than 30 m. mfd.

Points about Gang Condensers

All the points referred to above apply equally well to single or ganged condensers, but there are a few other requirements in respect to those of the latter type.

The spindle must be really rigid, and should be supported in bushes placed between each section. Trimmers, which are in effect small pre-set condensers, should be provided, and these should have easily accessible adjusting screws.

The Trimmers

A number of different forms of trimming condensers are used by various makers, but they nearly all work on the same principle as that shown in Fig. 4. By screwing down the adjusting knob the springy brass plate is pressed closer to the mica dielectric, and this increases the capacity. As a trimmer is connected in parallel with each section of the gang condenser, the different sections can be matched to compensate for unequal "stray" capacities set up by wiring, etc.

A different method of trimming is used on the condenser shown in Fig. 5. In this case the end moving vane of each section is split, and is set further away from the next fixed vane than are the others. As a result the capacity of any condenser section can be adjusted at any part of the dial by pressing the appropriate sector of the split vane towards the adjacent fixed ones.

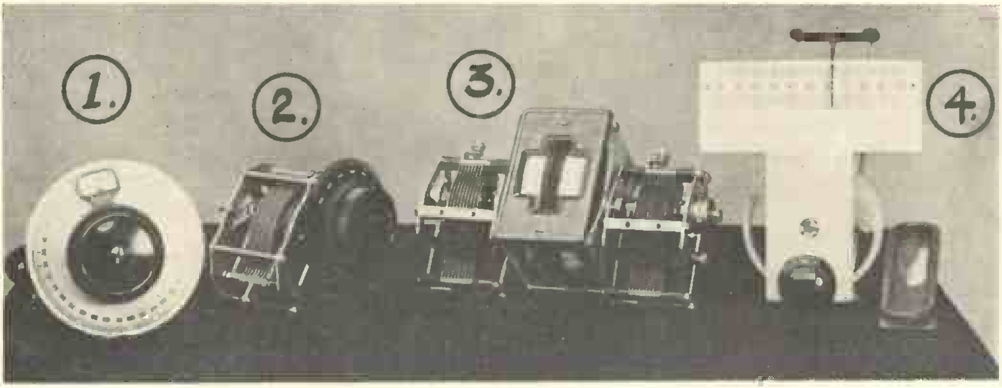


Fig. 7.—Different Forms of Condenser Drives.

1. A micro-dial; 2, a condenser with plain and vernier operation; 3, a dual-gang condenser with separate drum control; 4, a straight-line dial.

Split End-Plate Condensers

Split end-plate condensers are largely employed by set manufacturers, but are not generally available to amateurs. They can be matched with perfect accuracy over the whole tuning range, but require rather expert handling.

Condenser Drives

Whilst on the subject of variable condensers we must give some consideration to the methods of operating them. A plain dial used to be sufficient, but with the present need for extreme selectivity some kind of slow-motion or vernier drive is generally essential. The most usual type is that used on the gang condensers shown in Fig. 1. It is used in conjunction with a small escutcheon, or "window," fixed to the panel. This type of drive is available with different reduction ratios from about 5 to 1 to 20 to 1; the former is more convenient when tuning is not unduly critical, and the latter for extremely sensitive and short-wave receivers.

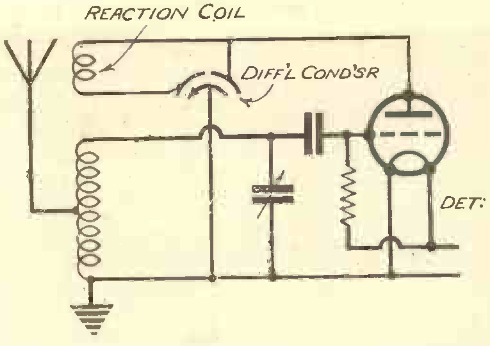


Fig. 8.—CONNECTIONS TO A DIFFERENTIAL REACTION CONDENSER.

Many gang condensers have a small knob concentric with the main one, and it is used to trim one particular section—a very convenient arrangement when the various coils are not exactly matched.

Other forms of condenser drives are shown in Fig. 7.

A "Micro-dial"

Number 1 is a "micro-dial," having an accurate hair-line cursor and a double 0 to 180 degree dial. It has two concentric knobs, the larger one giving direct drive, and the smaller a reduction of 100 to 1. This dial is especially intended for S.W. work, and for instruments which require very accurate adjustment or calibration.

Number 2 operates in a similar manner, but in this case the vernier movement is integral with the condenser, and does not form part of the dial itself.

Dual Gang Condenser with Two Drum Dials

The dual gang condenser number 3 has two drum dials, which can be operated together to give normal ganged tuning, or separately when either section requires to be trimmed. This type of drive is useful when the two condenser sections are used to tune two unmatched circuits, such as, for instance, a frame aerial and a tuned grid coil.

Straight-line Dial

Number 4 shows a new type of straight-line dial; as the knob is rotated the pointer moves over a horizontal scale. This type of dial is becoming very popular, principally due to the fact that it can be read very easily.

Differential Condensers—

Differential condensers are similar to ordinary variable condensers except that they have two sets of fixed vanes, and consequently three terminals (see Fig. 6). The moving vanes, which are connected to the centre terminal, can be put into mesh with either set of fixed ones, and are in fact generally partly in mesh with both.

Differential condensers are always of the straight-line capacity type, so that the sum of the capacities between the moving and both sets of fixed vanes remains constant and the capacity of the moving to each set of fixed vanes is proportional to the dial reading.

—and their Uses

These condensers are generally employed for reaction purposes, to keep the detector anode-earth capacity constant. This removes the probability of tuning being upset by reaction adjustments. The usual method of connecting a differential reaction condenser is shown in Fig. 8.

Connect Moving Vanes to Earth

In using all types of variable condensers the moving vanes should be connected to earth. It removes the difficulty of "hand-capacity" due to touching the operating knob and, also, if a metal panel were used it would be earth-connected and the moving vanes would be in contact with the panel.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SERVICING MARCONIPHONE 330

TUNING COILS

MAKING AN AUTO TIME SWITCH

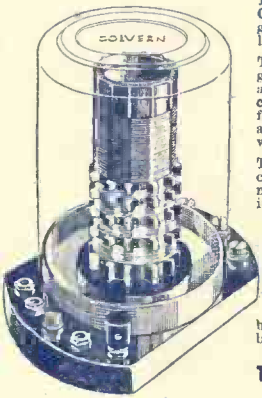
REMOTE CONTROL SYSTEMS

1/-

Part 12

IN ABOUT 24 WEEKLY PARTS

COLVERN
T.D. COIL
AN UP-TO-DATE COIL WITH UP-TO-DATE FEATURES



TYPE T.D., an entirely new COLVERN COIL, designed to give super selectivity on both long and broadcast wave-bands.

The coil is completely screened, giving a very neat appearance, and incorporates tapped aerial coupling and reaction, while the four alternative aerial tappings are arranged as sockets with a wander plug.

The first two tappings give aerial couplings similar to those normally employed but with greatly increased selectivity.

Nos. 4 and 5 give a high degree of selectivity with weak aerial coupling—suitable for use in a "swamp" area.

A most important feature of this coil is that there is no break through on the long waveband from B.B.C. stations.

TYPE T.D. - Price 8/6

Our 1933 Booklet Radio List No. 10 is now available and free on request.

COLVERN LIMITED
MAWNEYS RD. · · · ROMFORD, ESSEX

—and your batteries should be
Exide
AND
Drydex

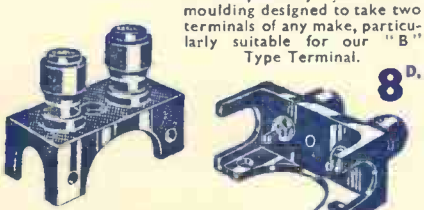
There is a type for every set.

MOUNT YOUR TERMINALS NEATLY ANYWHERE—

With the Belling-Lee Bakelite Terminal Mount, terminals may be mounted anywhere, anyhow—vertically or horizontally. On the baseboard or screening box, the window ledge, wall or skirting board, etc.

An exceptionally neat bakelite moulding designed to take two terminals of any make, particularly suitable for our "B" Type Terminal.

8D.



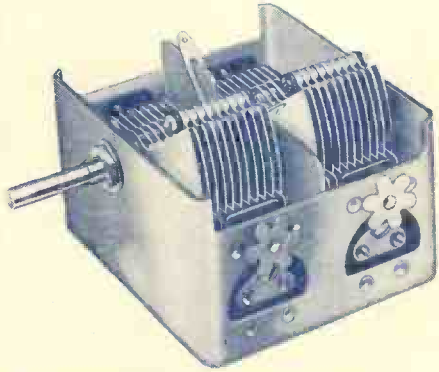
Write for complete list of Radio Connections.

Patent.

BELLING-LEE
FOR EVERY RADIO CONNECTION

Advt. of Belling & Lee Ltd., Cambridge Arterial Road, Enfield, Middlesex.

N U G A N G



Rigid one-piece chassis—very robust construction. *Accurately matched to within ½ m.mfd. plus ½ per cent.* Trimmer to each stage. Supplied semi-screened as illustrated or fully screened with lid. Capacity ·0005.

SEMI-SCREENED		FULLY SCREENED	
2-gang - -	14/-	2-gang - -	16/-
3-gang - -	21/-	3-gang - -	23/6
4-gang - -	28/-	4-gang - -	31/-

PRECISION INSTRUMENTS

Advertisement of Jackson Bros. (London) Ltd., 72 St. Thomas' St., London, S.E.1. Telephone: Hop. 1929.

SERVICING

THE MARCONIPHONE RADIOGRAM III MODEL 330 FOR A.C. MAINS

THE Marconiphone Model 330 Radiogram consists of a three-valve radio unit having band pass tuning, screened grid MS4B Marconi H.F. Valve, Marconi MH4 detector valve and Marconi MPT4 pentode output valve, supplied with high-tension D.C. by a Marconi U10 full wave rectifier valve.

The loud speaker is a Marconi permanent magnet moving coil instrument; the resistance of coil is 9 ohms approximately.

Fig. 1.—CONNECTING THE AERIAL TO GRID CIRCUIT OF DETECTOR VALVE TO ELIMINATE H.F. CIRCUIT.

The motor is the Marconi high speed synchronous A.C. motor with friction clutch (see motor notes on p. 306). An automatic switch brake stops the motor at the conclusion of all His Master's Voice eccentric groove records.

THE ARRANGEMENT OF THE RADIO CIRCUIT

The Aerial Coupling

The aerial is coupled to the first band pass tuning circuit by three alternative taps; one direct and the other two *viâ* small tubular condensers, C1 (·0001 mfd.) and C2 (·000018 mfd.) — the most selective tap.

Mains Aerial

The mains cable and wiring can be employed by connecting the fixed condenser C17 (·001 mfd.) to one of the aerial sockets, the other side of C17 being connected to the mains *viâ* an orange wire.

The Colour Wiring Code

The wiring of the radio unit is coloured to conform to the colour code wiring scheme standardised by the Marconiphone Company; the colours are as follows:—

a. Black . . True earth circuit.
b. White . . Cathode when not at earth potential.
c. Red . . H.T. positive. D.C. circuit.
d. Green . . Grid (all grid circuits in A.C. and D.C. mains).
e. Blue . . Pick-up.
f. Brown . . Heaters A.C. and D.C. (not battery).

g.	Pink . .	L.S. output after condenser or transformer.
h.	Purple, violet or mauve .	Aerial.
j.	Orange . .	Mains.
k.	Yellow . .	Anode.
l.	Yellow with red tracer.	Screen of screen-grid valve.
m.	Yellow with black tracer	Pentode screen.
p.	Green with black tracer.	Bottom of grid circuit not direct to earth.

The Tuning Circuits of the 300

A double tuned band pass circuit is employed between the aerial sockets and the H.F. valve. The aerial coils, " L1 " and " L2 " are tuned by ganged condenser —VC1, the grid coils of the H.F. valve " L3 " and " L4 " being tuned by ganged condenser " VC2."

The H.F. Stage

The screened grid Marconi MS4B valve is indirectly heated and provided with

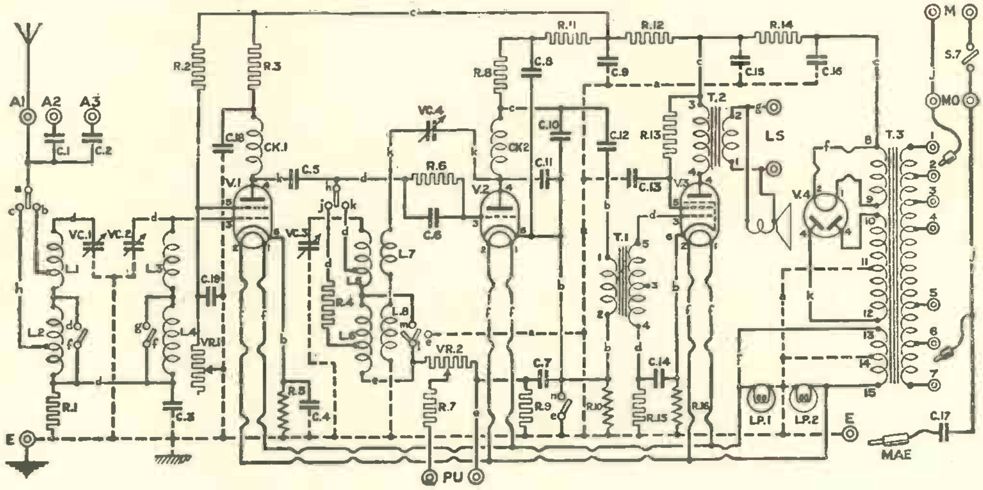


Fig. 2.—Theoretical Diagram of the Marconi 330 Receiver.
(Compare with Fig. 3.)

r.	Green with white tracer.	Mid position of tuning coil.

The circuit diagram (Fig. 2) is coded with the small letters " a," " b," " c," etc.

How the Theoretical Diagrams and Component Illustrations are Interlinked

Each component in the theoretical diagram is numbered such as " C1," " R13," " T2," etc.

These numbers will also be found on the component illustration, Fig. 3.

This method enables the service engineer to find any component without the necessity of having to trace out wiring. If this scheme is used correctly it will be found that any component can be located with great rapidity and certainty.

grid bias by the bias voltage dropping resistance R1 (2,000 ohms).

The Detector Grid Circuit

Signals are passed from the H.F. valve anode circuit *viâ* coupling choke CK1 and coupling condenser C5 (·0005 mfd.) to the detector tuning circuit, " L5 " and " L6," which are tuned by ganged condenser " VC3."

Details of the Reaction and Volume Controls

The reaction coils " L7 " and " L8 " are wound on the same former as the detector grid coils " L5 " and " L6 " (" L8 " is situated inside the former—see Fig. 3).

Reaction is controlled by the variable

condenser VC4 which is mounted on the main volume control shaft on which is also mounted VR1, the H.F. valve screen volts variable resistance and VR2, the pick-up volume control.

How Radio Volume is Controlled

When the volume control shaft is rotated in a clockwise direction the variable resistance VR1 (red and yellow wire), increases in value, and by-passes less screen voltage to earth. When this has reached a maximum value the vanes of the condenser VC4 commence to engage, introducing capacity reaction, thus still further increasing volume.

Pick-up Arrangements

The Marconiphone Type 14 pick-up (D.C. resistance of coil 6,000 ohms approximately) is connected *viâ* the blue sockets and R7 (200,000 ohms) to the lugs of the pick-up volume control (blue wires) which is mounted on the main volume control shaft.

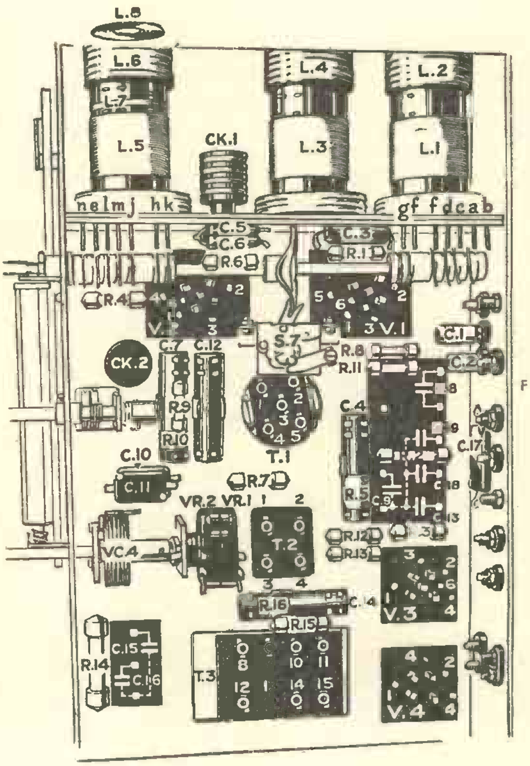


Fig. 3.—The Component Layout of the Marconi 330 Receiver.

Wave Change "On-Off" Switch

This switch in medium wave position short-circuits out the long-wave coils "L2," "L4" and "L6" respectively in addition to shorting out the long-wave reaction coil "L8."

In long wave position the short circuiting contacts of the wave change switch open and allow the long wave coils to function in series with the medium wave coils, "L1," "L3," "L5" and "L7" (reaction).

In the "Gramophone" position contacts "l," "e" and "m" close, passing the signal from the volume control VR2 to the grid of the detector valve *viâ* the medium wave tuning coil "L5," switch contacts "l" and "k" and the grid leak and condenser "R6" and "C6." At the same time contacts "m" and "e" open, allowing bias dropping resistance R9 to operate between the cathode of the detector valve and earth (dotted wire), thus biassing the detector valve to enable it to operate as an amplifier of the signals from the pick-up.

Low-Frequency Coupling between Detector and Pentode Valve

Signals from the detector valve are resistance capacity coupled by R8 (35,000 ohms) and C12 (·1 mfd.) to the primary of the intervalve transformer, the secondary of which is connected between grid and cathode of the pentode valve which is biassed by the dropping resistance R15 (10,000 ohms).

How to Fit a New Pointer Driving Cord (see Fig. 5)

Type of Cord.—Employ a superior flax fishing line having a breaking strain of approximately 40 lbs. Approximate length for one instrument, 40 inches.

(1) Tie a single knot in end of cord and thread cord through holes in one end of spring 5 and fibre strip 6.

(2) Pass cord through slot in condenser driving disc and proceed in direction of arrow, passing cord over rear pulley.

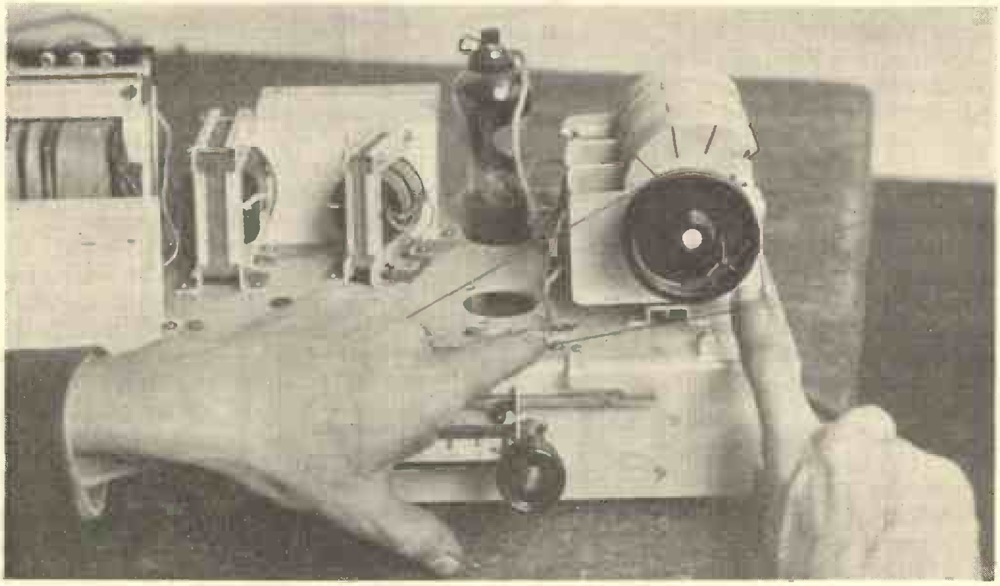


Fig. 4.—Where to put your Fingers when Fitting a New Cord to the Marconi 330.

(3) Six complete turns should be made (in a clockwise direction) around the condenser control spindle and the end of cord passed over the front pulley.

(4) Ignore clip 4 and pulley 3 for the moment and proceed (*viâ* route 2) and make one complete turn on condenser drum.

(5) Pass cord through slot in drum, holes in 5 and 6, and after pulling cord tight tie a knot in cord as close to strip 6 as possible.

(6) Tension the cord by pressing down and slipping under pulley 3 (Fig. 5).

Note.—The stops on the tuning control should not prevent condenser vanes from fully engaging. Should this occur, slacken grub screw on condenser drive and adjust.

How to Adjust Scale Pointer

Tune in a station of known wavelength (medium wave preferred), and move pointer to register wavelength as near as possible (see Fig. 6). Without altering position of tuning control, insert cord under clamp plate 4 and grip with screw.

The Right Way to Take the Radio Unit out of the Cabinet

Warning.—Make no "live chassis" tests unless loud speaker or phones are connected to the output or the pentode may be damaged.

The pentode should be taken out if other parts of the circuit are being tested live.

Note.—When ordering spare parts or corresponding, the chassis number, which will be found on an aluminium plate on back L.H. side of chassis, MUST be quoted in addition to the serial number of the instrument.

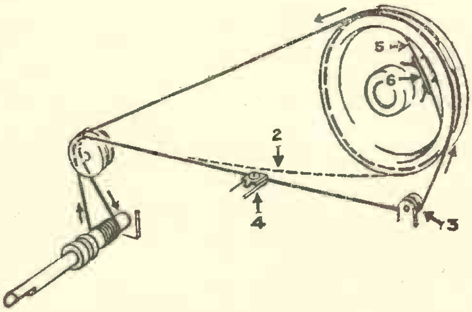


Fig. 5.—Showing how the Cord is Tensioned by pressing down and slipping under Pulley 3.

(1) Remove valves and put in safe place.

(2) Remove control knobs by unscrewing grub screw.

(3) Remove four chassis retaining screws (do not loose spring washers or metal plates).

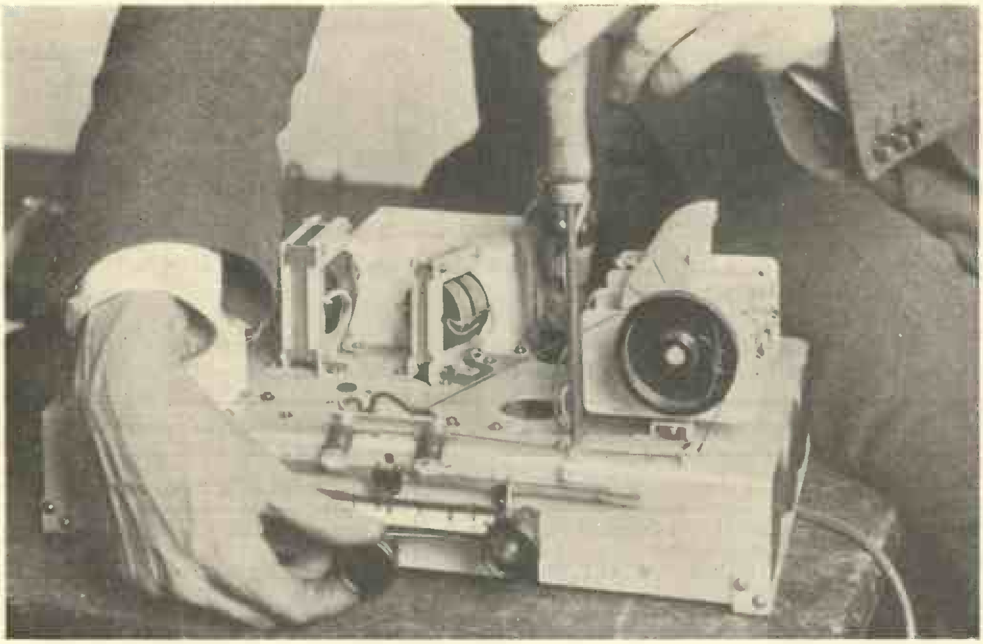


Fig. 6.—This shows the method of setting the Scale Pointer.

(4) Unsolder loud speaker leads at pink sockets.

(5) Slide chassis out, *taking care not to catch mains transformer on metal bracket.*

(6) Turn tuning control so that moving plates of ganged condenser are fully engaged with the fixed plates (to protect them).

***Note.*—The greatest possible care should be taken of the ganged condenser.**

To examine unit turn on side, so that unit rests on side nearest mains transformer.

Table of Resistance and Condenser Values

Resistances :

R1	2,000 ohms.
R2	50,000 ,,
R3	10,000 ,,
R4	2,000 ,,
R5 and C4 Decoupler unit	6,000 ohms and 0·1 mfd. condenser mounted inside black former.
R6	·5 megohm.
R7	200,000 ohms.
R8	35,000 ohms.
R9	1 megohm.
R10 and C7 Decoupler unit	1,000 ohms, and 0·1 mfd. condenser mounted inside black former.
R11	10,000 ohms.
R12	5,000 ,,
R13	10,000 ,,
R14	1,000 ,,
R15	10,000 ,,
R16 and C14 Decoupler unit	375 ohms, and 0·1 mfd. condenser mounted inside black former.

Fixed Condensers :

C1 Tubular	·0001 mfd.
C2 ,,	·000018 mfd.
C3	·01 mfd.
C4 and R5 Decoupler unit	·1 mfd. and 600 ohms.
C5	·0005 mfd.
C6	·0001 mfd.
C7 and R10 Decoupler unit	·1 mfd. and 1,000 ohms.

C8 . . In block 1·0 mfd.
C9 . . 4·0 mfd.
C10 . . ·0005 mfd.
C11 . . ·0005 mfd.
C12. (in black tube) . . ·1 mfd.
C13 . . 4·0 mfd.
C14 and R16 Decoupler unit . . ·1 mfd. and 375 ohms.
C15 . . In block 4·0 mfd.
C16 . . 4·0 mfd.
C17 . . ·001 mfd.
C18 . . In block 1·0 mfd.
C19 . . In block ·5 mfd.

Rapid Condenser Check Table

This table serves to indicate a broken-down condenser or its alternative.
Do not take tests with :—
(1) Set " live."
(2) Valves in or external apparatus (such as loud speaker) connected.
(3) Measure from condenser lug to frame of radio unit.

Condenser.	Correct Result.	Possible Causes for Incorrect Result.
C4 (white lug) .	600 ohms.	R5 burnt out. C4 down to earth.
C7 . . .	One side, 1 megohm (top lug). Other side— Switch M.W. or L.W. short. Switch gram. 1,000 ohms.	C7 down to earth. Switch making bad contact (points 'n' and 'e'). R10 burnt out.
C8 . . .	One side open. Other side— Switch M.W. or L.W. short. Switch gram 1,000 ohms.	C8 down to earth, C10, 11, 12 or VC4 down to earth. Switch contacts 'n' and 'e' making bad contact. R10 burnt out.
C9 (top lug) .	Open.	C9 down to earth.
C12 . . .	One side open (top lug). Other side— Switch M.W. or L.W. 1,000 ohms. Switch gram 2,000 ohms.	C12 down. C10, 11, 8 or VC4 down to earth. Primary T1 (lugs 1 and 2) burnt out. Switch contacts 'n' and 'e' not connecting. R10 or primary T1 (lugs 1 and 2) burnt out.
C13 . . .	Open (bottom right-hand lug of can).	C13 down to earth.
C14 . . .	One side 375 ohms (left lug). Other side 10,000 ohms (right lug).	R16 burnt out. C14 down.
C15 . . .	Open (top lug).	C15 down to earth. C9 or C16 down to earth.
C16 . . .	Open (centre lug).	C16 down to earth. C15 down to earth. Winding of T3 down to earth (lugs 8 and 9).
C18 . . .	Open.	C18 down to earth.
C19 . . .	Between approx. 500 ohms and open according to position of VR1.	C19 down to earth. VR1 burnt out.

Note.—If a condenser is suspected, detach the wire from a lug and insert a milliammeter having a range of 0 to 50 m.a. to show the presence of a shorted or leaky condenser.

An Avometer should be used for preference. Set same to 120-m.a. scale and then switch to 12-m.a. scale if necessary.

How to Locate a Fault in the Radio Unit

If the set is absolutely "dead," but valves appear O.K. and the pilot lamps are all right, the low-frequency section should be checked back methodically in the following manner.

The Output to Loud Speaker (see Fig. 7).

Place the test phones across the wires attached to the pink loud-speaker socket. Good headphone strength signals should be heard here. If they are, check up the loud speaker carefully for continuity of leads and speech coil and correct centring of the coil in the magnet gap. *Do not forget that a fault may develop in the flexible leads to the coil as well as the coil itself.*

If no signals are heard, or they are thin and distorted, remember that the output transformer is the link between them and the pentode output valve. Follow the pink wiring from the sockets and apply the headphones across lugs 1 and 2 of the low-resistance output winding of the transformer. If no signals are heard here, check up the secondary winding. The D.C. resistance should be about ½ ohm.

Having checked up here, go back to the primary winding (lugs 3 and 4—red and yellow wires), listen across here. *Be careful in clipping* on earphones, as this winding is in the anode circuit of the pentode valve.

The Output of the Pentode Valve

If the winding is O.K. (the D.C. resistance is approximately 450 ohms), good signals should be good headphone strength, but rather high pitched. If the primary winding is "dis" the headphones will receive the full H.T. and anode current of the pentode and signals will be lower in tone but still rough in quality.

How to Check Up the Pentode Valve and its Voltages

Take the valve out and check up by testing at the valve pins and screen terminal for inter-electrode contacts. Only the filament pins should show continuity. When testing other contacts gently tap the valve while tests are being made to reveal an intermittent short circuit if it is there.

The voltages at the valve holder with the valve out should be as follows :—

Anode socket (yellow wire) to frame of unit : 350 volts.

If this is low, suspect the rectifier valve output by checking the voltage from lug of the mains transformer (red and brown wires) to the frame of the radio unit ; having temporarily disconnected R14. This is the output of the rectifier valve, and if voltage is low—below 260 volts D.C.—exchange the rectifier valve.

An Apparent Discrepancy

Note that only 260 volts may be expected when the red wire is disconnected from R14, but that when R14 is reconnected the value should rise to about 350 volts. The reason for this apparent discrepancy is that when measuring "raw" rectified A.C. the meter measures the average of the rectified peaks ; when, however, the condenser smoothing system C16 and C15 is brought into play by reconnecting the red wire to R14, the fact that the condensers, due to their smoothing action, tend to fill in the "valleys" between the "peaks" enables the meter to register a higher voltage, viz. 350 volts.

If the voltage 250 is O.K., but a serious drop below 350 is noticed when R14 is re-connected, suspect a short to earth on one of the subsidiary voltage dropping resistances, such as R2 (H.F. screen), or R8 (detect. anode), or their associated wiring.

The voltage from the screen tag of the pentode to frame should be in the neighbourhood of 325 volts, and the anode current ("emission") about 30 milliamperes.

The Input to the Pentode (see Fig. 8)

The next place to listen is between the grid (green wire) and cathode (white wire) sockets of the pentode to check the input to the valve. The signals here should be soft but clear and of good quality. If this test fails, suspect the coupling between the detector valve and the pentode.

Testing the Intervalve Transformer (see Fig. 9)

The intervalve transformer (T1) is resistance coupled from the anode circuit of the detector valve, so that the resistance R8 (35,000 ohms), and therefore R11 (10,000 ohms), and R12 (5,000 ohms) will have to be taken into account.

Place the headphones across lugs, 4 and 3 of T1 (the secondary winding) and see if the signal has arrived safely there. If it has, check the wiring from lug 4 and 3; there may be a dry joint or an "earth." Signals at this point should be quiet but clear and of good quality.

If the test fails, check up the secondary winding; the D.C. resistance should be about 10,000 ohms.

Next place the headphones across the primary winding (lugs 1 and 2, white wires); quite good quality signals should be heard. It should be noted that this test does not prove the continuity of the primary winding of the intervalve transformer, but it does check up R8 and particularly C12 (·1 mfd. in the block moulded tube on the left of the transformer) and the fact that the detector valve is getting its H.F. signal and rectifying it correctly.

The Output of the Detector Valve

If the above tests fail a test must be made directly in the anode circuit of the detector valve and the valve itself checked up for voltage supplies, emission and internal shorts.

Signals obtained by the insertion of headphones in the anode circuit of the detector valve either by cutting the yellow wire or the use of an adaptor should again be quiet but clear with a pronounced click when the phones are connected (H.T. current).

Checking the Detector Valve

The emission of this valve should be about 3 milliamperes with switch in "M.W." position. If this is not present check for continuity of the heater across the pins and for H.T. volts. The H.T. voltage between anode socket and frame should be about 260 volts with the valve out.

How to Check Back Detector H.T. Supply

If no H.T. is found at the anode socket resistance R8 (35,000 ohms), R11 (10,000 ohms) and R12 (5,000 ohms) will have to be checked up.

Place the negative clip of the voltmeter on the chassis framework and touch the metal end caps of there resistances with the positive clip as follows (look at Fig. 3 to find the components) :—

Left-hand end of R8, 250 volts. Right-hand end, 300 volts.

Left-hand end of R11 (next to R8), 300 volts. Right-hand end, 325 volts.

Right-hand end, R12, 325 volts. Left-hand end, R12, 350 volts.

The fixed condensers C11 (·0005 mfd.), C10 (·0005 mfd.), C8 (1 mfd.) and C9 (4 mfd.) should also be checked for leakage by removing one lead and inserting a milliammeter.

Using a Pick-up as a Final Check Signal (see Fig. 10)

If after having checked the low-frequency circuit right through no signals are heard, finally check up this portion of the circuit by connecting a pick-up and, having checked the signal to the detector valve, listen again as the fault may be in the radio side of the job, *i.e.*, the tuning coils, etc.

With the scale set in the "gramophone" position by the right-hand switch knob, signals from the pick-up should be heard across VR2 and between grid socket and cathode socket of the detector valve holder.

How to Check the H.F. Side of the Radio Unit

Test to see if there is evidence of correct reaction, if not, suspect a fault in the reaction coils (L7 and L8) or the coupling variable condenser "VC4" which is mounted on the same spindle as the volume controls VR1 (for radio) and VR2 (for pick-up control).

How to Check the Reaction Coils

Place the switch in the "M.W." position and measure for continuity between the shaft of the variable condenser VC4 and the gramophone unit. The resistance of the two coils should be approximately 4·0 ohms. The same resistance should be shown with the switch in the "L.W" position.

Fig. 7.—TESTING THE OUTPUT OF THE 330 UNIT.

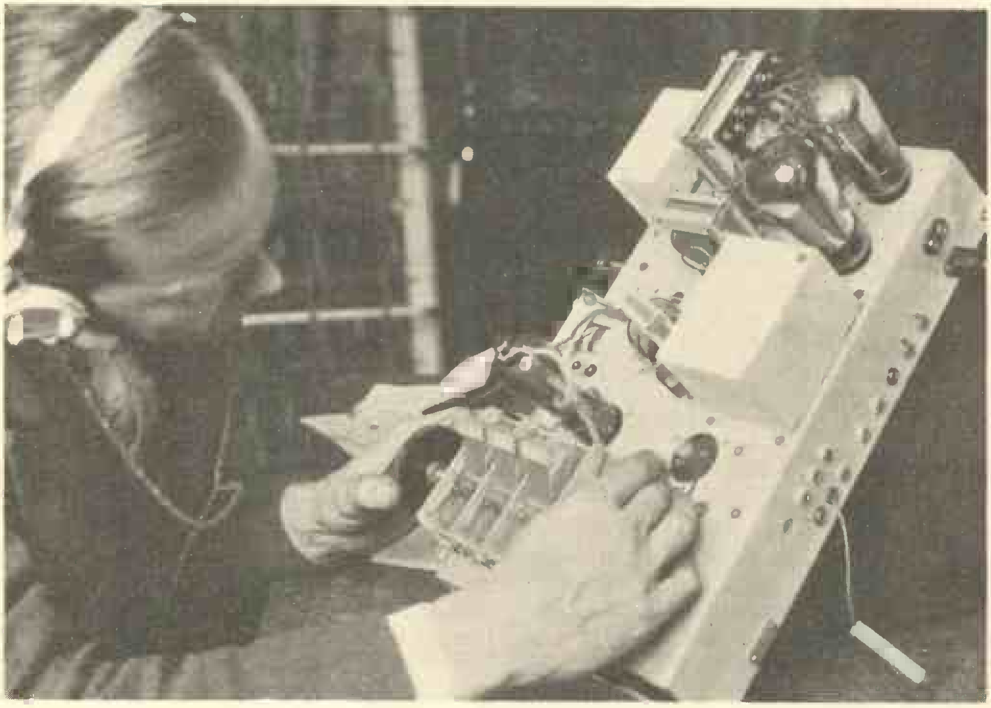


Fig. 8.—CHECKING THE INPUT TO THE PENTODE.

How to Check the Three Tuned Circuits

Having established that the L.F. side of the instrument is "O.K." the high-frequency side of the instrument must now be checked up. The best plan is to connect up the aerial and tune the instrument to a powerful signal. If nothing is heard apply the aerial wire to the unsoldered lug of the trimmer condenser of the *back* section of the gang (VC1) and slightly adjust tuning. If signals are heard now the fault must lie in the purple wiring from the three aerial sockets in the tubular condensers C1 (·01 mfd.) and C (·0005 mfd.).

How to Check the Aerial Coils (see Fig. 2)

Check for D.C. resistance between the right-hand end of R1 and the green wired lug of VC1 (*back* section of ganged condenser). With the switch in the "MW" position the resistance should be about 2·5 ohms and with the switch in the "LW" position about 19·5 ohms.

When turning the switch look out for flickering of the meter needle in either position, which may suggest that the switch contacts need cleaning.

The resistance from the right-hand end of R1 to chassis should be 2,000 ohms approximately, and from the left-hand end a short to chassis frame (dotted earth line in theoretical). From the green lug of VR1 to chassis frame should read 2,000 ohms. If less, suspect a short to earth in the coils somewhere, or in associated wiring.

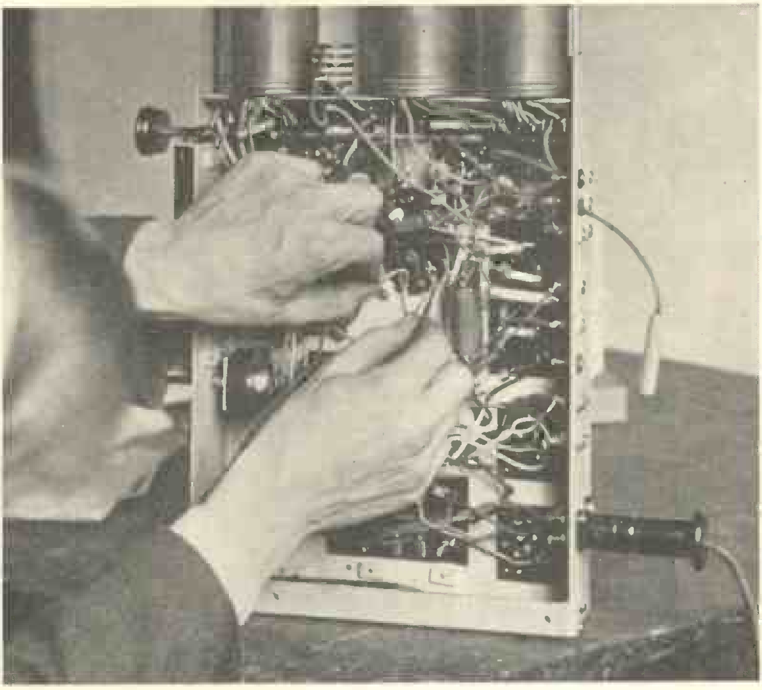


Fig. 9.—Testing the Intervalve Transformer.

How to Check the H.F. Grid Coils

These coils "L3" and "L4" are tuned by VC2, the centre condenser of the ganged condenser. Connect the aerial to the green lug of VC2 (near the metal screened anode lead of the H.F. valve) and slightly readjust the tuning: if a signal is heard less selectivity must be expected, as we have eliminated the aerial coils by the band pass circuit (L and L2).

If no signals are heard, the continuity of the coils L3 and L4, and the switch contacts "j" and "f" may be checked by measuring between the green lug of VC2 and the right-hand end of R1. The resistance of L3, the medium-wave coil, should be about 2·5 ohms (switch in "MW" position), and the combined resistance of coils L3 and L4 (long-wave coil) should be about 19 ohms. *Note* that if C3 (·01 mfd.) is faulty, signals will be affected.

The connection between the grid socket of the H.F. valve and the green lug of VC2 should also be checked. A short circuit between the vanes of either VC1 or VC2 would, of course, affect a signal.

Checking Up the H.F. Valve

The emission of the H.F. valve should be about 1·5 milliamperes, and the H.T. volts to the anode about 220 volts to the chassis frame with the volume control at maximum.

If no H.T. volts are found, there must be a fault either in the flexible anode lead or in the high-frequency choke, CK1 (90 ohms), R3 (10,000 ohms). R12 has been already checked when checking the low-frequency side of the circuit.

The following voltages should be found on checking back along the H.F. anode circuit given above.

CK1 (red wire) approximately 300 volts to frame, yellow wire about the same, right-hand end of R3, 300 volts, left-hand end of R3, 320 volts.

Look Out for Broken Down Condensers

Whenever a voltage is low and it is known that the main H.F. supply is O.K., suspect any condensers connected to earth near the position of the circuit being tested.

In the case of the H.F. valve, there are C18 (fourth lug down on right of "can") and C5 (just under the H.F. choke), which is the H.F. coupling condenser to the tuned grid circuit of the detector valve.

Note that a short to earth in R2 or VR1 would affect the anode volts.

Checking the Screen Volts

R2 (50,000 ohms-long resistance over condenser "can") and C19 (·5 mfd. yellow and red wire to "can") should be checked back for a fault.

The volts to the screen of the valve should be approximately 50 volts *with the volume* control full on.

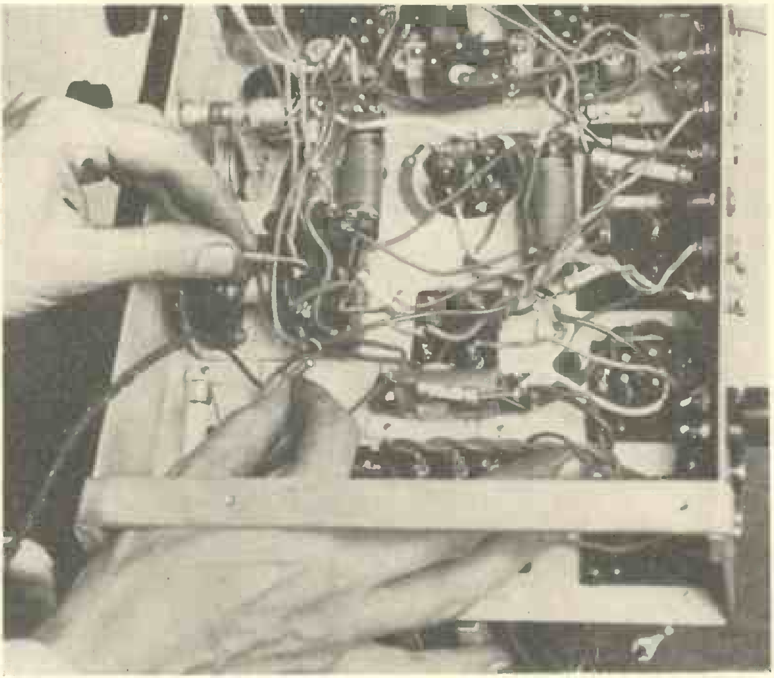


Fig. 10.—Checking Pick-up Signals across the Volume Control (Blue Wires).

Checking the Output Circuit of the "H.F." Valve (see Fig. 11)

If the grid circuit of the detector valve ("L5," "L6" and VC3), and the coupling choke CK1 and coupling condenser C5 are O.K., signals should be heard, but selectivity and strength will be poor. By placing the aerial on the anode tag of the H.F. valve, the selective band-pass circuit between the aerial and the H.F. valve is cut out of circuit, and the magnification of the H.F. valve is not present.

How to Check the Grid Circuit of the Detector Valve

The resistance of the coils may be measured between the green lug of VC3

Fig. 11.—Checking Coupling from H.F. Valve Output.

(front condenser of gang) and the frame of the unit. The resistance should be :—

With switch at "MW," 2·5 ohms approx.

With switch at "LW," 19·0 ohms approx.

Also check the continuity and correction of the grid leak R6 (below CK1—·5 meg.) and C6 (·0001 mfd. just above R6).

THE TURNTABLE MOTOR OF THE "330" (see Fig. 12)

How the Motor Works

This motor operates by virtue of the fact that the magnetic flux produced by the winding on the laminated magnetic poles induces currents in the copper bars of the rotor, and these produce sufficient reaction to the magnetic field to cause the rotor to revolve.

Warning.—In no circumstances attempt to hand-turn the rotor by

The Approximate Voltages and Emissions of the Valves of the "330"

When readings are being taken the volume control must be full on. All readings are taken on the Avometer scale indicated.

Valves.	Location.	Appearance.	Temp.	Function.	Anode Feed D.C. m/A.	Avo Scale.	Anode Frame Volts D.C.	Avo Scale.	Screen Feed Milliamps. D.C.	Avo Scale.	Screen Frame Volts D.C.	Meter Scale.	G.B. Volts.	Meter Scale.	Fil. or Heater Volts.
MH4 (V. 2)	Back left	No glow	Warm	Det.	3 Switch M.W. or L.W. 2 Switch Gram	·012A	200 Valve out 60 V. in.	1,200	—	—	—	—	Grid to Cathode Slight Ind.	12	4
MS4B (V. 1)	Front left	Glow	Warm	H.F.	V. con. max. 1·5 V. con. min. ·25	·012A	220 Valve out 170 Valve in	1,200	·75	·012	Valve out 45·0 35·0 Valve in	120	Grid to Cathode 1·0	12·0	4 A.C.
MPT4 (V. 3)	2nd row right	Glow	Hot	Output pentode	28·0	·12A	320 Valve out 240 Valve in	1,200 1,200	4·5 —	·012 —	320 Valve out 210 Valve in	1,200 1,200	Grid to Cathode 7·0	120	4
U10 (V. 4)	Right	No glow	Warm	Rect.	20·0 each anode	·12A	A.C.	—	—	—	—	—	—	—	—

Note 1.—When "Valve out" headings are given the other valves are assumed in. If all other valves except the U 10 are out, the "valve out" readings will be higher by 10 to 50 volts according to the Test point concerned.

Note 2.—Failure of emission may be due to open bias Resistors, such as R 5 (H.F. valve), R 9 (Det. valve), and R 16 (Pentode valve).

Note 3.—The Valves should be in position unless otherwise stated.

the governor balls; if it is found necessary, turn by governor sleeve.

The Friction Clutch

The motor is fitted with a friction clutch on the turntable spindle, designed to protect the rotor and worm gearing in the event of the turntable becoming jammed or being otherwise suddenly stopped (see Fig. 12).

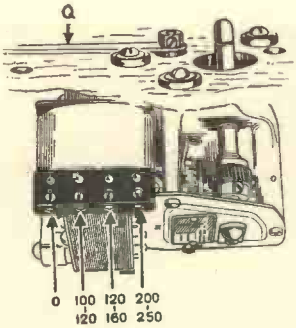


Fig. 12.—The Turntable Motor of the 330.

How the Clutch Works

This assembly consists of four parts :—

(1) A brass collar fixed to the spindle (20, Fig. 13).

(2) The fibre gear wheel movable on spindle (21, Fig. 13).

(3) Spring friction washer (22, Fig. 13).

(4) Brass clutch adjusting collar (23, Fig. 13).

How to Adjust the Clutch

The clutch adjusting sleeve should be adjusted so that the rotor revolves slowly when the spindle is turned by the fingers, *i.e.*, the spring friction washer (22, Fig. 13) should be fully compressed.

Warning.—Do not damage fibre gear with too large a screwdriver when adjusting sleeve screws.

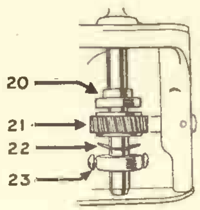


Fig. 13.—The Friction Clutch of the 330 Turntable Motor.

How to Dismantle the Motor (see Fig. 12)

Slack off set-screw fixing, and remove speed regulator (Q., Fig. 12). Do not lose rubber and metal washers.

Withdraw Magnet Unit as Follows :—

(1) Remove end bearing (10, Fig. 14) by unscrewing bolts 7 and 11. Do not disturb end bearing adjusting screw (9, Fig. 14).

(2) Remove metal spacers.

(3) Carefully withdraw rotor, if necessary separating governor by slacking screw securing governor sleeve to spindle of rotor.

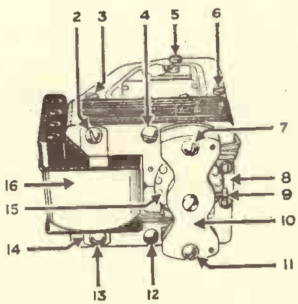


Fig. 14.—Details of the 330 Motor.

(4) Remove bolts 2, 4, 12 and 13. Do not lose nuts.

How to Remove the Magnet Winding

(1) Slacken bolts, holding strap 8 (Fig. 14).

(2) Gently open out two sections of magnet, using straps (8, Fig. 14) as hinges. Do not lose small brass pole locating rod (17, Fig. 16)

(3) Carefully withdraw winding bobbin. Do not lose large magnet strap.

How to Assemble the Coil and Magnet

(1) Slide on coil bobbin, taking care not to damage winding. If necessary, carefully pack bobbins tight on magnet core with strip of paper. Bobbin should be just tight on core.

(2) Place small brass locating rod in recess on top face of lower magnet pole (18, Fig. 16).

(3) Bend over top half of magnet into top of coil and down so that recess (18, Fig. 16) locates on brass locating rod lying in recess on lower magnet. To do this, insert upper magnet into bobbin as far as it will go and close the sections together carefully.

(4) Insert large magnet strap (14, Fig. 14) and replace unit on motor frame.

(5) Insert and screw up lightly the shore bolts 2, 4, 12 and 13 (Fig. 14).

Note.—The straps (8, Fig. 14) should be absolutely vertical.

(6) Replace metal spacers (19, Fig. 16).

(7) Replace end bearing, seeing that small holes locate on pins provided and oil hole is uppermost.

(8) Screw up tightly, but little by little, on each bolt alternately.

The rotor should be perfectly free, but there should be no end play on the bearings.

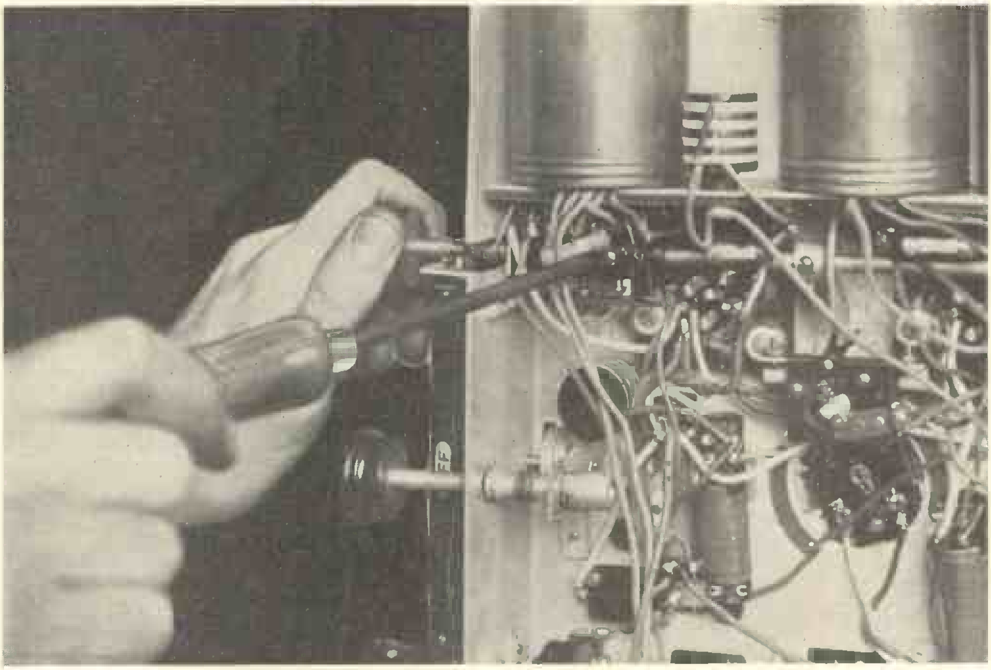


Fig. 15.—Tightening Grub Screw on Switch.

How to Remove the Governor and Rotor

(Do not attempt to turn governor or rotor except by the flange.)

(1) Remove end bearing as before (10, Fig. 14).

(2) Carefully withdraw rotor, if necessary slacking of screw securing governor to rotor spindle, taking great care not to damage the spindle or governor.

How to Remove the Main Spindle

(1) Withdraw bolts 2, 4 and 7 (Fig. 14).

(2) Unscrew three top-plate retaining screws 3, 5 and 6 (Fig. 14). Do not disturb bearing screw near centre of top plate. Note the locating "dimples" on underside of plate.

(3) Withdraw spindle.

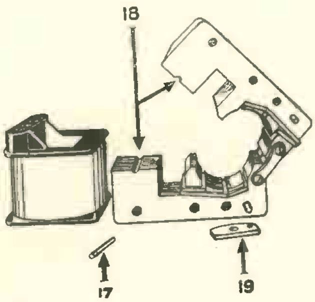


Fig. 16.—The Magnet Unit of the 330 Motor.

Electrical Data of the Motor

Resistance of Winding (see Fig. 12). Taps.	D.C. Resistance. Ohms.
0 to 200/250 . . .	138
0 to 120/160 . . .	55
200/250 to 12/160 . .	83
120/160 to 100/120 . .	18
100/120 to 0 . . .	37

"330" Motor Check Table

Symptom.	Cause.
Rotor revolves, but does not drive turntable.	Examine turntable bearings and brake for obstructions. Check clutch-adjusting sleeve fixing screws. Adjust clutch adjustment sleeve (23, Fig. 13) more tightly. Remove superfluous lubricant between clutch parts.

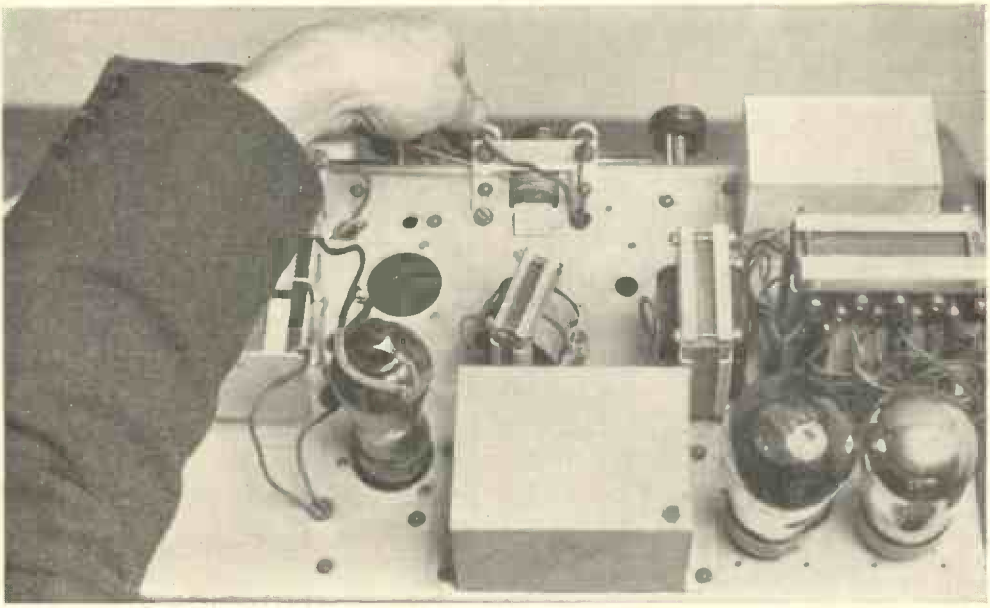


Fig. 17.—REPLACING THE PILOT LAMP.

Symptom.	Cause.
Motor appears to drag on loud passages (*i.e.*, slows down).	Voltage adjustment correct? See whether clutch is slipping and check up as above. Governor pushed too far into the body of the rotor, thus not allowing motor to attain correct speed, due to undue pressure on governor pad.
Motor fails to rotate.	Check electric supply to motor connecting contacts (Fig. 12). If O.K., check up magnet winding for continuity (see electrical data). Examine soldered contacts. Check for correct voltage adjustment. Examine switch and brake; look for obstructions or bent rotor spindle. See that the governor friction pad and speed control lever are correctly adjusted.
Motor hums.	Examine, and if necessary tighten magnet unit securing bolts 2, 4, 7, 11, 12, 13, especially 2 and 13 (Fig. 14).
Motor hums and gets hot.	Possible short between taps 100/120 and 200/250.

Symptom.	Cause.
Motor noisy.	Lack of lubricant? Governor bearings too tight? *Note.*—These bearings are slotted on the upper side to receive oil from vertical oil holes drilled in frame. These slots must be kept uppermost when replacing or adjusting bearings.
Motor weak with serious overheating.	Voltage adjustment correct? Possible short in section between 0 and 100/120 taps.

RADIO DEFECTIVE, "GRAM" O.K.

Faults on Long Wave only

No long wave.	Disconnection or short circuits L2, L4, L6 or L8. Faulty switch contacts, especially "d," "f," "l" or "k."
Poor long wave.	Tap on L2 "dis." Switch contact "g" touching end of "R1."

Faults on Medium Wave Only

Poor "M.W."	Examine and if necessary clean switch contacts and increase tension.

Faults on both "LW" and "MW"

Hum.	Short between anode and screen lead of MS4B valve. Defective earth.
Distorted radio.	MS4B inter-electrode short. MPT4 inter-electrode short or low emission.
Intermittent, Fading, Erratic } Radio	Inter-electrode short on MH4. Defective switch. Dry joints. Lugs of R1 and C3 touching. Dry joint in H.T. supply to MS4B or screen supply. Inter-electrode short in MS4B or MH4.
Faulty tuning. Tuning jambs.	Loose or broken driving cord. Loose grub screws. Scale jambing on escutcheon due to chassis having waved forward.
Poor sensitivity on radio (usually with poor selectivity as well).	Ganged condenser out of gang.
Poor sensitivity only.	Faulty MS4B. Faulty MH4. MS4B loose in holder. H.T. supply to MS4B defective. VR1 defective.
Crackle.	Loose or faulty MS4B. " VR1 " defective. Aerial touching something. Dirt in ganged condenser. Inter-electrode short on MS4B.

No Radio at All

	" CK1 " burnt out, or H.T. supply to MS4B or MH4 otherwise defective. MS4B heater " dis " or failure of heater voltage supply to valve holder. Earth or broken lead on tuning coil, especially MW coils.

Both Radio and "Gram" Defective

Hum.	Open detector grid circuit. Aerial or earth lead too near to mains wiring. Faulty switch, particularly contacts " l," " j " and " k."
No results.	R13 or R14 burnt out. Check U10 and high tension system generally.
No results—*continued.*	Check supply to heaters of valves. Check back. Examine loud speaker and leads and check output.
Crackle.	Inter-electrode "short" in MH4 or possibly pentode. Loose valve holders. Switch barrels loose (see Fig. 19, page 554).
Rattle. Distortion.	Loudspeaker out of distortion. Loose cabinet escutcheon.
Noisy switch.	Dirty contacts, insufficient tension on springs.

Faults on Gramophone Only

Distortion.	Armature of pick-up jambed on one side of magnet.
Hum.	R7 disconnected. Open pick-up circuit. Motor frame not earthed. Pick-up arm not earthed. Open detector grid.
Volume control inoperative.	Loose on spindle.
No record reproduction.	VR2 faulty. Broken pick-up lead. " Short " in pick-up lead. " Dis " pick-up coil. Dry joint in pick-up lead. Dry joint on R7.
Poor gram.	" Dis " in pick-up circuit. Faulty VR2. Worn needle.

THE PICK-UP OF THE 330

How to Check up the Pick-up

Failure of, or defective, gramophone reproduction may be due to the pick-up or its associated leads which are plugged into the blue pick-up sockets of the instrument.

The pick-up should be placed on a revolving record and test phones attached to the ends of the plugs. If no or poor signals are heard here, examine the plugs and leads carefully ; the resistance of the leads and pick-up coil should be about 6,000 ohms.

Clear crystal set strength music should be heard in the test phones if the pick-up is in order, if not, and the leads appear O.K., the pick-up lead will have to be removed.

How to Remove the Pick-up Lead

Unscrew the small grub screw on the underside of the pick-up arm and, allowing plenty of slack lead, pull the pick-up lead away from the arm, part the ball and socket clips. The pick-up can then be removed entirely by unsoldering the leads.

Now place the pick-up lightly on a record and attach the test phones to the two soldering lugs on the Paxolin sheet and listen.

If signals are heard here the pick-up leads are at fault, and should be examined for :—

(*a*) a short circuit,
(*b*) a break,
(*c*) a short to the metal pick-up arm.

If no, or distorted, signals are heard the actual movement of the pick-up is defective.

A resistance test will show whether the coil itself or the leads from the coil to the soldering lugs are defective. If this test fails the coil will have to be replaced. The D.C. resistance of the coil should be about 6,000 ohms.

If distorted or very weak music is heard, the armature is probably displaced or there is dust or filings in the pick-up magnet gaps.

How to take the 330 Pick-up to Bits

Read these instructions right through before you start, as otherwise damage may be done or the pick-up incorrectly re-assembled.

The pick-up consists of three main parts. *The magnet*, which is of the permanent horseshoe type and which is provided with two pole pieces bolted on to the ends of the magnet by two hexagonal-headed bolts.

The armature which consists of an upper and lower portion with two bearings at the centre, the lower portion carrying the needle screw, the upper end being flattened and which vibrates between the magnet poles. The flattened end of the armature is held in position by a small piece of rubber sheet, which is in turn secured by a metal plate.

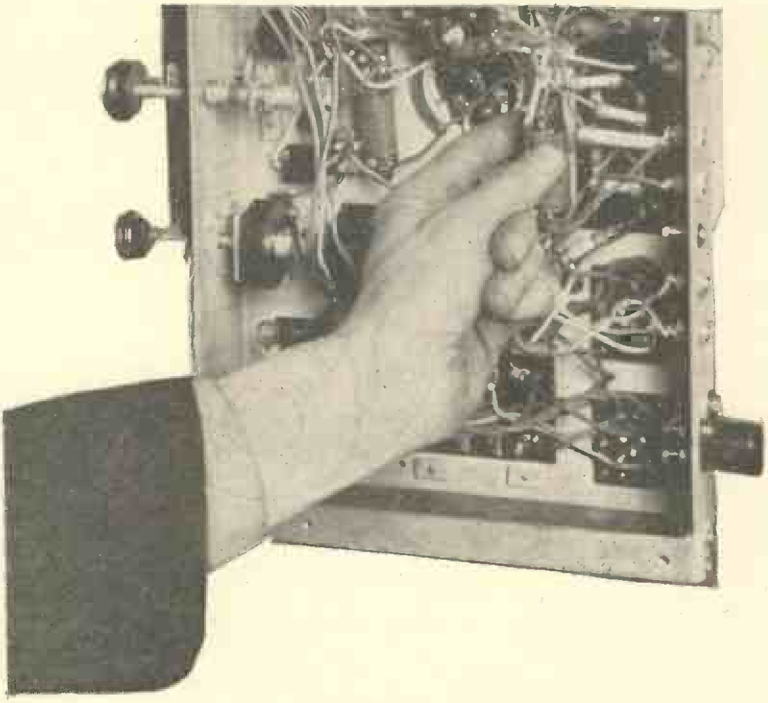


Fig. 18.—A Decoupler Unit.

This rubber sheet is designed to prevent the flattened end of the armature from leaving the central position between the magnet poles and vibrating on or sticking to one of them. If this does happen, distorted music or very weak reproduction will result.

Remove the metal cover of the pick-up and proceed as follows :—

(1) Take away the two pole pieces from the magnet ends by removing the two

hexagonal-headed bolts and carefully slide off the magnet placing a steel " keeper " down the pole ends. Care must be taken to see that the rubber sheets or tubes round the pick-up bearing are not lost; put these and the pole pieces on one side where they will be free from dust.

(2) If the coil has not already come out with the pole pieces slide it out, and, if on testing it for continuity and resistance it is found defective, replace it with a new coil.

Carefully examine the joints between the coil and the wires to the soldering lugs to see if the fault is there and not in the coil itself before fitting a new coil.

Be very careful to keep all dust away.

How to Rebuild the Pick-up

Insert the coil in one side of a pole piece and stand the pole piece up on its end. This will make it easier to fit the armature into position.

Now insert the armature into the centre of the coil, remembering that when the coil and pole pieces are reassembled that the flattened end of the armature must be uppermost, and that the threaded hole in the armature for the middle screw must face outwards.

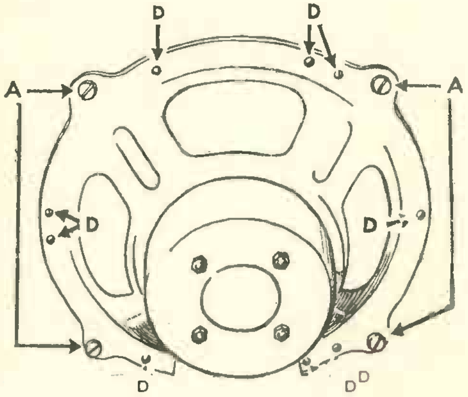


Fig. 19.—The 330 Loud Speaker Unit.

How to Fit the First Pole Piece

If two small rubber bearing sheets are found instead of tubes, place these carefully in position round the bearings of the armature so that the sheets lie between the armature bearings and the two curved recesses in the pole pieces into which the bearings fit.

When doing this make sure that the point where the two edges of the rubber sheets meet does not occur at a point where the pole pieces grip the armature spindle.

How to Fit the Second Pole Piece

When the rubber sheets have been arranged slide the other pole piece on to the coil, being careful at the same time to keep the rubber sheets in position—a pin is useful for this. Having placed the second pole piece in position, hold the two pole pieces between the finger and thumb fairly tightly, thus clamping the armature and coil between the two pole pieces. The flattened end of the armature should now be adjusted so that it lies in the centre of the coil and equidistant from either pole piece.

The pole pieces, coil and armature may now be reattached to the pole pieces by reinserting the hexagonal-headed bolts and screwing them up lightly; be careful that the flattened end of the armature still remains central between the two pole pieces and that the needle hole in the other end of the armature is exactly in the centre of the hole in the moulded base of the pick-up.

Now, making quite sure that the bearings of the armature are firmly gripped by pinching the two pole pieces together, finally tighten the two hexagonal-ended bolts and slide the magnet back into position so that the ground surface is downwards. Take great care to remove all traces of dust or metal filings from the magnet.

The Use of the Rubber Damping Sheet

This sheet, which is held in position by the metal plates, can, it will be found, be moved slightly from side to side, due to the fact that the two screws which secure the plate locate into slots. This movement is provided for a final adjustment of the central position of the flattened end of the armature between the pole pieces. If the flattened end of the armature is not exactly central the reproduction of treble may be deficient, and if the end of the armature is so far over that it can touch a pole piece, distortion or " chatter " may result.

Look again carefully for dust before the Pick-up Cover is replaced.

THE LOUD SPEAKER OF THE MODEL 330

Permanent Magnet

This is a low-resistance moving coil unit the D.C. resistance of the coil of which is approximately 9 ohms. The magnet is of the "strap" variety, and the bolts securing it to the cone supporting frame must be on no account disturbed.

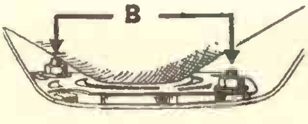


Fig. 20.—THE CENTRE "SPIDER."

How to take the Cone out (see Figs. 19, 20 and 21)

If the coil requires renewing, or the magnet gap cleaning, the cone will have to be removed. Blowing through a magnet gap is of little use except as a temporary measure, since dust, especially metallic dust, merely shifts its position, and eventually reassembles in the air gap again.

The cone is secured to the cone supporting frame by a three-section metal ring under the felt ring, to which the three sections are stuck by a special adhesive. The felt ring and three sections of the metal ring can be detached together by removing the screws "D" (Fig. 19). Do not try and remove the felt ring and metal ring sections separately.

The apex of the cone and coil former is secured to the face of the magnet by a Paxolin "spider" shown in Fig. 20, by the nuts "B." Remove these nuts, but do not touch any other screw or bolt heads, otherwise the relative positions of the cone supporting frame and the magnet unit will shift with the result that great difficulty may be experienced in recentring the cone again.

Having freed the ends of the two flexible leads to the coil the cone may now be lifted out. If the coil is faulty, do not attempt to rewind it and make quite sure that the "dis," if there is one, is not in the leads from the coil and not in the coil itself.

If the coil is O.K., examine it carefully to see that it is perfectly round in shape and free from dust.

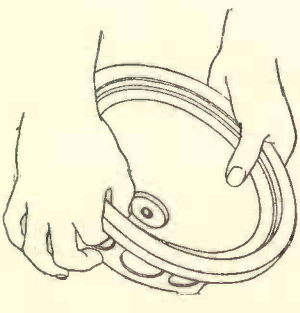


Fig. 21.—ADJUSTING THE CONE.

How to Clean the Magnet Gap

The best way of seeing any dirt or dust in the gap is to shine a torch light up from the underside of the gap, this will show any dirt or dust up at once.

The most satisfactory method of removing dust is to insert a thin slip of plasticine into the gap to which dust and dirt will adhere and by which it can be removed from the gap. Wiping with cloth or such things as pipe cleaners tends only to shift dust from one place to another without entirely removing it.

How to Insert a new Cone and Coil

Place the loud speaker unit on its back and carefully lower the cone and coil into position so that the holes in the Paxolin "spider" fit over the two bolts "B" (Fig. 20). Be very careful not to damage the cone or coil by dropping it or forcing it in any way.

Now lay over the rim of the cone the felt ring to which should be attached the three sections of the cone clamping ring, so that the holes in the sections of the ring coincide with the holes in the frame. Having registered the hole correctly, reinsert the screws "D" (Fig. 19), but do not tighten them up too much until the position of the cone has been adjusted.

How to Centre the Coil in the Magnet Gap

See that the nuts in the spider securing bolts are slack and move the cone gently from side to side with an elliptical motion until the coil movement cannot be felt against the magnet poles.

Now connect the loud speaker up and, tuning some loud signals and adjusting the coil position until all "buzz" disappears, finally tighten up the nuts on the coil securing bolts.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc., (Lond.)

SECTION V—INDUCTANCE AND ITS CALCULATION

TUNING coils and chokes can be obtained in a wide variety of shapes and sizes. Some coils are wound in several layers and others in a single layer; some chokes have a great amount of iron used in their construction, and others are simply large multi-layer coils wound in several sections and without iron. They all have one thing in common, however, something possessed by every piece of wire, whether straight, curved, or bent into any other configuration; whether two inches or two miles long. That something goes by the name INDUCTANCE. In order to consider what is meant by this term we must leave coils for the moment and discuss magnets.

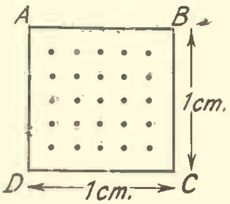


Fig. 1.—DIAGRAM SHOWING FLUX DENSITY.

Magnetic Force

Most readers are well acquainted with the word "force." It conveys an idea of action, a force pushing or pulling or causing something to move. A magnet possesses a force, called MAGNETIC FORCE, which acts on iron and a few other rarer metals such as nickel and cobalt. Any substance or material on which magnetic force can act—*i.e.*, a material which is SUSCEPTIBLE to magnetic force—is called a magnetic substance. When the mathematician says that a FIELD OF FORCE surrounds a magnet he only means that the magnet has the power to attract or repel certain objects with a certain force. Some magnets are more powerful than others—*i.e.*, their field of force is stronger. The mathematician must have some means of distinguishing between the powers of magnets and so he speaks of the LINES OF FORCE, and measures the NUMBER OF LINES in the field of force, or MAGNETIC FIELD.

Lines of Force

We cannot point to a particular line and say that it is a line of force, but what the mathematician did when he invented lines of force was this: He took a magnet and balanced the force with which it attracted a piece of iron by means of weights. He already had names for the units of mechanical force—1 pound weight, 1 ton weight, 1 gramme weight, and so on—and he was thus able to express magnetic force in terms of pounds weight and grammes weight. Then he said that, for simplicity, a field which attracts (or repels) with a force of one unit will be called a field having one line of force. That which exerts a force of two units, a field with two lines of force, and so on.

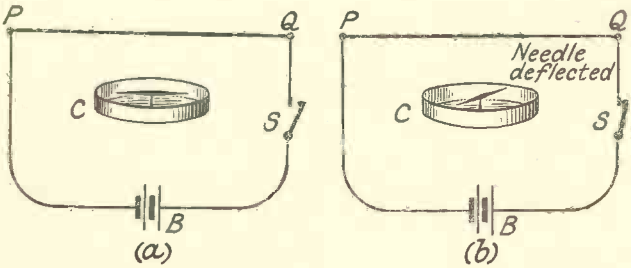


Fig. 2.—A SIMPLE EXPERIMENT TO SHOW THAT A WIRE BEHAVES LIKE A MAGNET.

The force exerted by a magnet

varies according to the distance away from the magnet at which the force is measured. That is to say, the number of lines at any point in the field surrounding a magnet varies according to the distance of the point from the magnet. The field is most powerful near to the ends (or POLE PIECES) of the magnet.

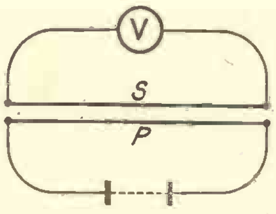


Fig. 3.—DIAGRAM TO ILLUSTRATE INDUCTION.

How Number of Lines are Expressed

The number of lines at a point refers to the number over a small area at the point. Suppose that we take two very thin flat pieces of iron each in the shape of a square, one of side 1 inch, and the other of side 2 inches—*i.e.*, with an area four times that of the first piece. If we place these in turn at the same point in the field of a large magnet, the force on the second piece will be four times the force on the first piece, because the area over which the force acts is four times that over which it acts in the first case. Thus we see that when we state the force of a magnetic field at any point we must also state over what area that force was measured. The number of lines are usually given as the number over a unit of area, either over 1 square inch or over 1 square centimetre. It is important to note that the area chosen must always be perpendicular to the lines of force.

Flux Density

Thus, in Fig. 1 if the square ABCD represents an area of 1 square centimetre, then the lines are perpendicular to the page, and the twenty-five dots represent the points where the twenty-five lines of force pass through the area. The mathematician sometimes uses the term FLUX DENSITY instead of "the number of lines of force." Thus in the case of a moving coil loud speaker the flux density, or number of lines, in the speech coil gap would be, say, 10,000 lines per square centimetre.

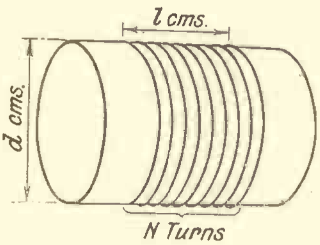


Fig. 4.—A SIMPLE SINGLE LAYER COIL WOUND ON A CYLINDRICAL FORMER.

Calculation of Total Flux

From the definition of flux density we see that the TOTAL FLUX over an area is equal to (the number of lines per unit area) × (the number of units of area)—*i.e.*,

Total flux (B) = flux density (n) × area (A).

or

$$B = nA \quad . \quad . \quad (1)$$

A Simple Experiment showing how a Wire behaves like a Magnet

Now when a wire is carrying a direct current a magnetic force is created around the wire. In other words, the wire behaves like a magnet and is capable of attracting and repelling magnetic substances. The simple experiment illustrated in Fig. 2 demonstrates this. B is a battery connected to a wire, of which a straight portion PQ is arranged to pass immediately over a small magnetic compass C. The circuit to the battery is completed *viâ* a switch S. The direction of PQ should be made to coincide with the north-south line of the compass needle. When the switch S is closed (*b*) the compass needle will be deflected and will remain in a deflected position. When the circuit is broken the needle returns to its normal position (*a*). The same effect is observed if an ordinary magnet is brought near to the compass needle, hence we must infer that a magnetic force has been created by the current in the wire.

An Alternating Current produces a Dynamic Field

When an alternating current is passed through a wire the magnetic field which is created around the wire is a variable, or DYNAMIC, field and not a fixed, or STATIC, field. The field grows as the current strength rises from zero to a maximum, and when the current reaches its maximum value the field is also at a maximum. As the current decreases to zero and reverses so the field decreases and commences to grow again in the opposite direction, giving a reversed field corresponding to the negative half cycle of the current wave. The whole process is exactly similar to the periodic variation of alternating currents and voltages which we have already considered.

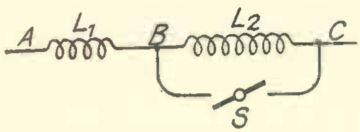


Fig. 5.—Two Coils joined together in Series.

Induction

Suppose that we take two wires P and S and arrange them as in Fig. 3. The ends of P are connected to a source of alternating current, and the ends of S to a voltmeter which indicates alternating voltages. We shall find that an alternating voltage exists across the ends of the wire S, although apparently no current is passing through it since it is not connected to the alternating current source. If we move S so that it is closer to P and still parallel to it the voltage indicated by V is increased, and when we increase the distance between the two wires the voltage reading is decreased. This effect is known as INDUCTION, and it is due to the wire S being placed in the variable magnetic field around the wire P. The more intense the part of the field in which S is placed, the greater is the induction effect, and *vice versâ*.

Only a Dynamic Field causes Induction

If we connect the ends of P to a battery, or to any direct current supply, instead of to the alternating current source, no voltage is indicated by V when the current is switched on. We should notice a slight flick of the voltmeter needle as we switched on, but not a constant reading. The induction occurs only when the field linking the two wires is a variable, or dynamic, field. This accounts for the slight flick of the needle just as the current is switched on, for at that instant the field around P is growing from zero (no current passing) to its steady value (the static field due to the direct current). This growth is momentary and causes momentary induction.

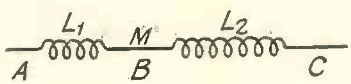


Fig. 6.—Diagram showing mutual Inductance.

The Effect of Induction in a Coil

From the word "induction" we have derived our term "inductance." Thus we see that inductance has to do with an effect which occurs when a wire is placed in the dynamic magnetic field around a second wire. When we have a coil consisting of several turns of wire and carrying an alternating current, the current in each turn of the wire creates a magnetic field which induces a voltage in every turn of wire in the coil. The more turns of wire on a coil, the greater the induction effect. The induced voltages can be added together and the mathematician has a formula which tells him the voltage across a coil due to an alternating current in the coil. The effect of induction is to cause a coil to offer *greater* resistance to alternating currents than to direct currents, and this is dealt with in another article. In order to distinguish between the induction effect which occurs when two coils are placed near to each other from the induction between the turns of a single coil the former effect is called MUTUAL INDUCTION and the latter SELF INDUCTION.

Calculating Inductance

We are able to calculate how great is the induction effect of a coil, and the calculation depends on the knowledge of such factors as the shape of the coil, its size, the gauge wire used in its construction, and so on. The induct*ance* of a coil is the mathematician's measure of the extent of the induct*ion* effect. Inductance is measured in "henries" and in submultiples of a henry, viz., millihenries and microhenries, the millihenry being $\frac{1}{1000}$th of a henry, and the microhenry $\frac{1}{1000000}$th of a henry. Expressing these relations in the form of equations, we have:

10^3 millihenries = 1 henry,

10^6 microhenries = 1 henry, and hence
10^3 microhenries = 1 millihenry.

Formulæ relating to Coil Inductance

There are several formulæ which we may use to calculate the value of the inductance of coils. Our choice of formula must depend to a great extent on what type of coil we are considering. Special formulæ have had to be invented for dealing with multi-layer and unusual shaped coils. Let us consider the simple case of a single layer coil wound on a cylindrical former. Such a coil is usually termed a "solenoid." The radius of the cylinder, the length of the winding and all other measurements must be made in centimetres and not inches, and all measurements in inches must be converted into centimetres. Fig. 4 shows a diagram of the simple coil we are considering. The diameter is d centimetres, the total length of the winding is l centimetres, and N is the total number of turns on the coil. Then :—

Inductance = $9{\cdot}87 \times 10^{-3} \times (\text{diam.})^2 \times (\text{No. of turns})^2 \times$ (a certain number, called K) ÷ (length),

i.e., $L = 9{\cdot}87 \times 10^{-3} \times d^2 \times N^2 \times K \div l$,

or $L = 9{\cdot}87 \times 10^{-3} \times \dfrac{d^2N^2}{l}$ K microhenries . . . (2)

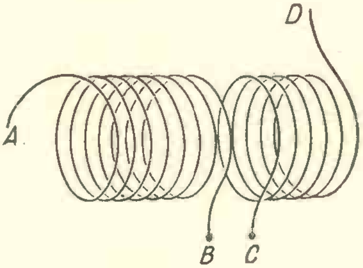


Fig. 7.—MUTUAL INDUCTION BETWEEN COILS WOUND IN OPPOSITE DIRECTIONS.

The letter "L" is the mathematical symbol for inductance, and the number K depends on the ratio of the diameter of the coil to the length of the winding, viz., $\frac{d}{l}$. The table in the adjoining column shows the value of K for different values of $\frac{d}{l}$.

An Example

As an example of the use of the formula of equation (2), suppose that we wish to find the inductance of a coil of 100 turns of wire on a $2\frac{1}{2}$-inch diameter former, the length of the winding being $1\frac{1}{2}$ inches. Firstly, we must convert these measurements to centimetres, which we can do if we remember that 1 inch = 2·5 centimetres (approximately). Hence :—

$2\frac{1}{2}$ inches = 6·25 centimetres.
$1\frac{1}{2}$,, = 3·75 ,,
Therefore, d = 6·25 centimetres.
l = 3·75 ,,
N = 100

$$\frac{d}{l} = \frac{625}{375} = \frac{25}{15} = \frac{5}{3} = 1{\cdot}7 \text{ approx.}$$

The value of $\frac{d}{l}$ is actually 1·66 . . ., the figure 6 recurring, but our answer will be sufficiently accurate if we take this to the nearest first decimal place, viz., 1·7. From the table we see that the value of K corresponding to $\frac{d}{l} = 1{\cdot}7$ is K = ·56.

Therefore we have :—

$$L = 9{\cdot}87 \times 10^{-3} \times \frac{6{\cdot}25 \times 6{\cdot}25 \times 100 \times 100}{3{\cdot}75} \times {\cdot}56 \text{ microhenries.}$$

and working out the arithmetic, we find that

L = 576 microhenries (approximately).

$\frac{d}{l}$	K	$\frac{d}{l}$	K
·0	1·0	1·4	·61
·1	·96	1·5	·60
·2	·92	1·6	·58
·3	·88	1·7	·56
·4	·85	1·8	·55
·5	·82	1·9	·54
·6	·79	2·0	·53
·7	·76	5·0	·32
·8	·74	10·0	·20
·9	·71	20·0	·12
1·0	·69	30·0	·09
1·1	·67	40·0	·07
1·2	·65	50·0	·06
1·3	·63	100·0	·03

Effect of Induction in Wireless Circuits

The effect of induction is highly important in wireless circuits ; in fact, were it not for induction we should be unable to tune a circuit so as to receive signals of different wavelength. In a tuning circuit (which is dealt with in another article) the greater the inductance used the longer the wavelength to which the circuit tunes. Most modern receivers cover two wavebands—called the medium and the long wavebands—and a switch is provided for effecting the change over from one waveband to the other. The action of the switch is well known ; it generally short-circuits a section of the tuning coil for the medium wave position, and switches the extra section of the coil into circuit on the long wave position.

Inductance between Two Coils

Fig. 5 shows two coils joined together in series. Coil AB has an inductance of L_1 microhenries (mH) and BC of L_2 mH. The switch S short circuits BC when closed, and the inductance in circuit is L_1. When S is open, the inductance is the total effect of L_1 and L_2 joined in series. If the two coils are some distance apart, or screened from each other, then the total inductance (L) is obtained by adding L_1 and L_2 together, thus :—

$$L = L_1 + L_2 \qquad . \quad . \quad . \quad . \quad . \quad (3)$$

If the two coils are close to each other, as they would be if wound on the same former, each will be within the dynamic field of the other, and hence the separate induction effects of each are enhanced by interaction. The interaction between two coils is what we have already termed mutual induction. It is measured as so much inductance, just as is the self-induction effect of a single coil.

Mutual Inductance

The letter M is used as a symbol for mutual inductance in mathematical shorthand. Thus, in the circuit of Fig. 6, if AB and BC mutually affect each other, so that their mutual inductance is M microhenries, the total inductance (L) in the circuit is obtained by adding up the enhanced inductances of each coil, thus :—

$$L = (L_1 + M) + (L_2 + M)$$
$$\text{or } L = L_1 + L_2 + 2M \qquad . \quad . \quad . \quad . \quad (4)$$

If we take two coils which are wound in opposite directions, as in Fig. 7, and place them together as shown and connect the ends B and C, the mutual induction effect will detract from the self-induction effects of each coil. Thus we have :—

$$L = (L_1 - M) + (L_2 - M)$$
$$\text{or } L = L_1 + L_2 - 2M \qquad . \quad . \quad . \quad . \quad (5)$$

Two coils placed together and connected in this way are said to be negatively coupled.

Variometers

In the case of the variometer, where we have one coil rotating within a second coil, the effect of a complete rotation through 180° is to change the mutual inductance between the coils from positive to negative. In Fig. 8 AB and CD are the two coils, and by rotating CD, so that the mutual inductance changes from positive to negative, we change the total inductance of the circuit from $(L_1 + L_2 + 2M)$ to $(L_1 + L_2 - 2M)$. The amount by which we have changed the inductance is

$$(L_1 + L_2 + 2M) - (L_1 + L_2 - 2M) = 4M.$$

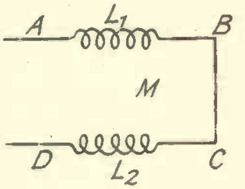


Fig. 8.—Mutual Induction in the case of Variometers.

That is to say, that the change in inductance, due to rotation of the coil, is four times the mutual inductance between the coils. The bigger we can make this change the wider the tuning range we can cover. Hence, in designing a variometer, we should endeavour to make the mutual inductance between the coils as large as possible in order to cover a wide range of wavelengths. Variometers are seldom used in modern receivers, but the problem illustrates the application of mathematics to the design of apparatus.

Another important design problem, solved by means of equation (2) and the table for K, is "What is the shape of the most efficient coil which may be constructed from a given length of wire?"

TUNING COILS

HOW TO CHOOSE AND USE THEM

By FRANK PRESTON, F.R.A.

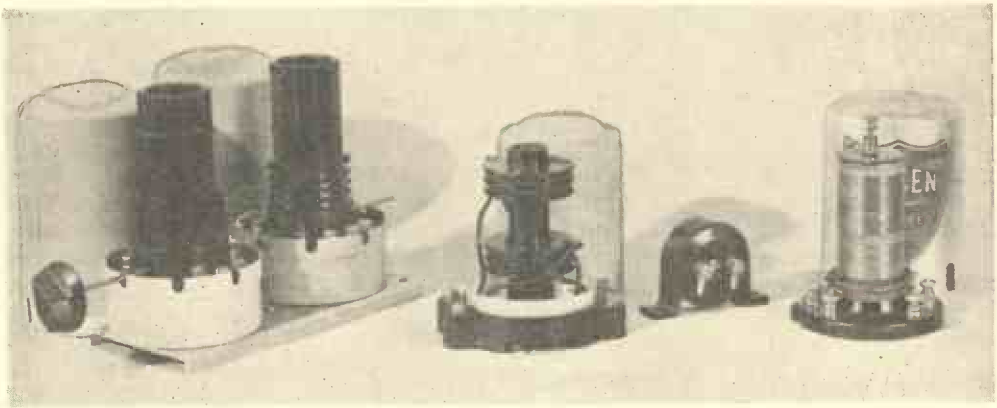


Fig. 1.—Some Examples of Modern Tuning Arrangements.

From *left to right :* (1) a pair of Colvern coils (one S.W. and one broadcast) forming a four-range tuner ; (2) a Colvern intermediate transformer ; (3) a Lissen "anti-breakthrough" choke ; (4) a Lissen screened dual range tuner.

WHENEVER a new circuit is evolved its principal difference from other circuits is almost invariably associated with the tuning arrangements. Generally speaking this is as it should be, because the tuning system is undoubtedly the most important part of any receiver, for it can either make or mar the performance.

The above-mentioned fact explains the reason for the multitude of different tuning coils on the market. Several of these coils are of similar types, designed by different makers, but there are, nevertheless, innumerable definitely different types each of which is intended for a special purpose.

Effect of Tuning Coils on Quality

The design and form of the tuning coils have an important bearing on the sensitivity and selectivity of the receiver in which they are employed. The same coils can also have a far reaching effect on the quality of loud speaker reproduction. This latter point will be referred to in more detail later on.

TYPES OF COILS

Let us consider the various *types* of coils in reference to the purposes for which they are intended.

Dual Range Aerial Tuner

We will begin with the well-known dual range aerial tuner fitted with a reaction winding. This class is represented by the Lissen Aerial Tuner, British General Tuner, Ready-Radio D.R. Coil, a series of Colvern Coils, Lotus Tuner, Telsen Dual Range Tuner, and many others of different makes.

The coils under consideration have three windings and are connected in circuit as shown in Fig. 2. The terminal numbers are not indicated because, unfortunately, no two makers follow the same system of numeration. For reference purposes the three windings are marked A B and C.

Winding A is the aerial winding and is not tuned, B is the grid winding and is tuned by the usual ·0005 mfd. variable condenser, whilst C is the reaction winding and is used in conjunction with a reaction condenser of about ·0003 mfd. capacity.

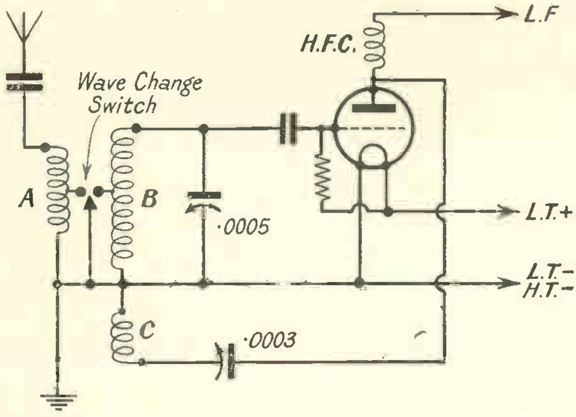


Fig. 2.—Connections of the usual type of Dual Range Aerial Coil.

It will be seen that windings A and B are tapped, the tapping points being taken to a 3-point wave-change switch which serves to short-circuit a portion of each winding when medium wave reception is required.

When to use a Dual Range Aerial Tuner

This type of coil is intended principally for tuning a receiver of the Det.-L.F. kind, but can also be used under certain circumstances for tuned grid coupling between S.G. and detector valves.

How Selectivity is Controlled

Selectivity is controlled principally by the size and disposition of the aperiodic aerial coil and by the accuracy of reaction control.

Some coils of this type, notably the Colvern "T.D.," have a tapped aerial coil so that increased selectivity can be obtained by connecting the aerial to a lower tapping. As a matter of fact selectivity can be increased to almost any desired extent by this means but as the selectivity is increased sensitivity is correspondingly reduced. Most manufacturers therefore prefer so to proportion winding A that a suitable compromise between selectivity and sensitivity is struck.

There is a serious drawback to some dual range aerial coils. It is this: the more selective they are made the more do they impair the "quality" of the received signal. It is thus impossible to obtain both a high degree of selectivity *and* good quality by their use unless some form of correction device is employed.

This point can best be explained by making reference to the graph (Fig. 3). The curve shows the "response" of the tuned circuit to various frequencies when the mean frequency of the station to be received is represented by the vertical line rising from the figure 0.

The sharper the tuning is made the sharper becomes the peak of the curve, and thus the smaller the number of degrees on the tuning dial over which the station "spreads." But a signal is not made up of a single frequency for the musical frequencies occupy a certain band on each side of the mean carrier wave frequency. Actually they extend for about 4½ kilocycles on each side and therefore as the peak of the curve sharpens the response to higher musical notes (or frequencies) is diminished.

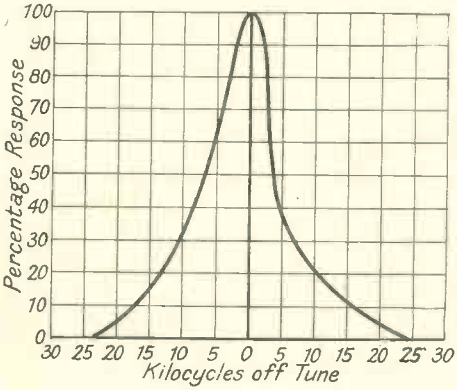


Fig. 3.—"Response Curve" of a Sharply Tuned Single Circuit Coil.

The result is that although the low notes are received at full strength, the higher ones are proportionately reduced in intensity.

Making up for High Note Loss

As mentioned before, it is possible to make up for the high note attenuation by the use of a correction device. The latter, which generally consists of a tone control transformer is inserted after the detector valve in the position indicated in Fig. 5. The particular transformer shown, by the way, is the Varley " Reactone."

A Rival to the Super-Het

Actually the kind of circuit typified by Fig. 5 has much to recommend it, and will, in my opinion, prove a serious rival to the superheterodyne. It is the basic circuit of the well-known Stenode receiver (dealt with fully in another article).

Band Pass Tuning

Another way of obtaining the required degree of selectivity, but which does not produce any high note loss, is to employ band pass tuning. Band Pass Tuners consist of two separate coils which have to be tuned simultaneously, preferably by means of a ganged condenser. Without entering into the theory of the band pass circuit it will be sufficient to say that the two tuned circuits are so arranged that although they produce a high degree of selectivity they always give equal response to a *band* of frequencies; in most cases a 9-kilocycle band width is chosen so that all musical notes will produce an equal response, and also because 9 kilocycles is the separation allowed between all high-powered European transmitters.

An ideal band pass response curve is shown in Fig. 6, and this should be compared with the curve of Fig. 3. The top of the former " curve " is practically flat and the sides vertical.

Band pass tuners specially suited to Det.-L.F. circuits are the Varley " Square Peak " Coil (named after the response curve), Lewcos Band Pass Filter and British General B.P. Coil. The methods of connecting these coils are similar, and their circuits resemble that of Fig. 7. In each case a coupling condenser having a capacity of from ·01 to ·05 mfd. is necessary and it is the capacity of this condenser (as well as the particular arrangement of windings) which governs the band width. As various makers adopt different winding arrangements, different capacities of coupling condenser are required in each case. It is therefore obviously essential that the exact capacity stated by the makers should be chosen. Incidentally it might be added that the coupling condenser must always be of the non-inductive pattern.

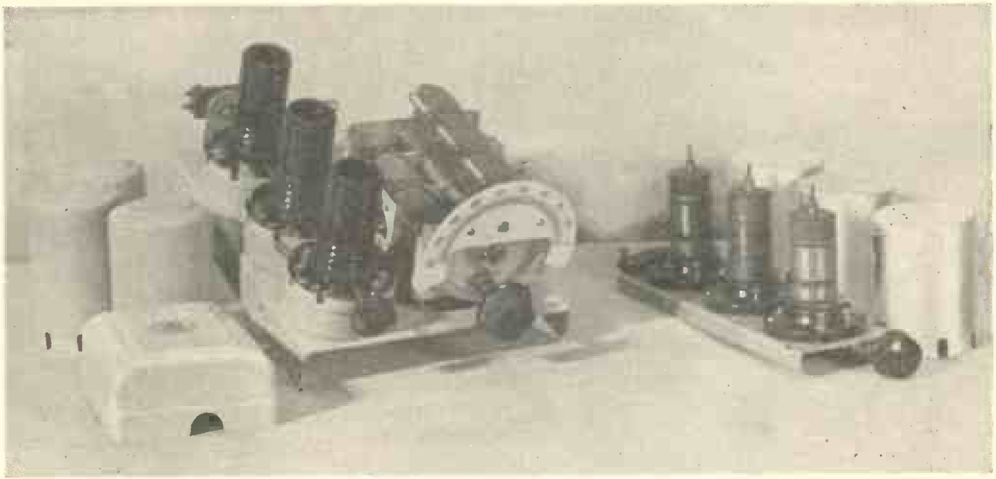


Fig. 4.—On the left is a complete Tuning Assembly made by Colvern's, and on the right a Lissen 3-Gang Coil Unit.

Kinds of Band Pass Filters

Band pass tuners of the type just referred to are known as "mixed filters" because the coupling between the two tuned circuits is made up of both capacity and inductance (the proximity of the two coils provides a certain amount of inductive coupling). The mixed filter is best for most purposes but there are other kinds of filters which are more suitable in special cases.

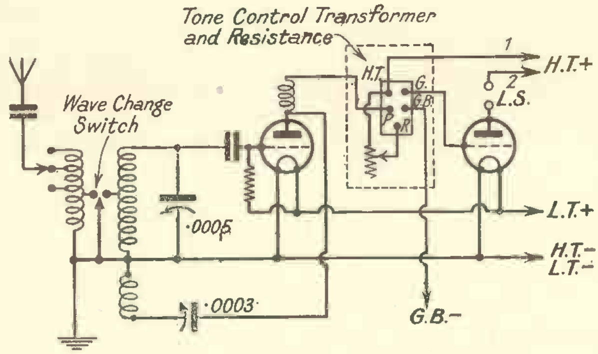


Fig. 5.—A "Tone-Correction" Circuit.

Capacity Filters

The first of these is the capacity filter, which has the same connections as those shown in Fig. 7, the only difference being that the two coils are shielded one from the other so that their inductive "fields" cannot link. The capacity filter is rather more selective, but is more efficient on the lower, than on the higher, wavelengths. As a result it is very suitable for use in a set having two or more tuned S.G. stages of which the selectivity varies in the opposite manner, for it then tends to make the performance uniformly good over the whole tuning range.

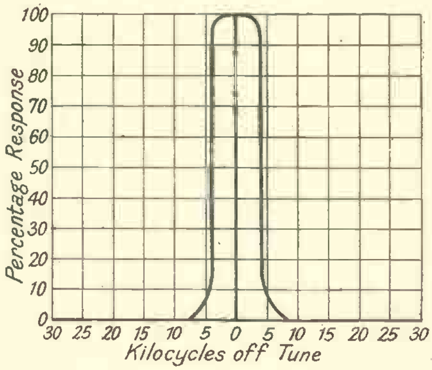


Fig. 6.—An ideal "Response Curve" for a Band Pass Tuner.

Inductive Filters

The inductively coupled filter, of which a circuit is given in Fig. 8, has properties just the reverse of the capacity filter and should not, therefore, be used in a multi-S.G. receiver. It is, however, very satisfactory for use in certain superheterodyne circuits because the capacity of the coupling condenser associated with other types of filter is liable to be the cause of long-wave interference in a superheterodyne. The inductive

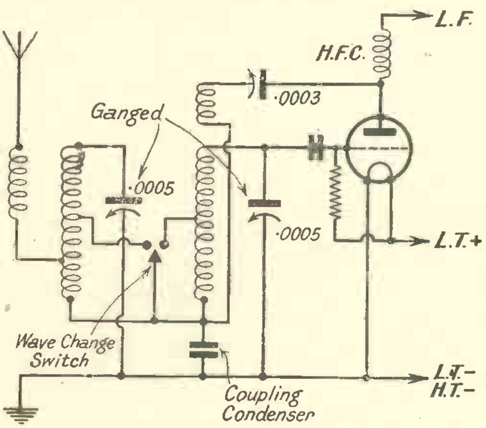


Fig. 7.—Circuit of a typical B.P. Filter for use with Det.-L.F. Receivers.

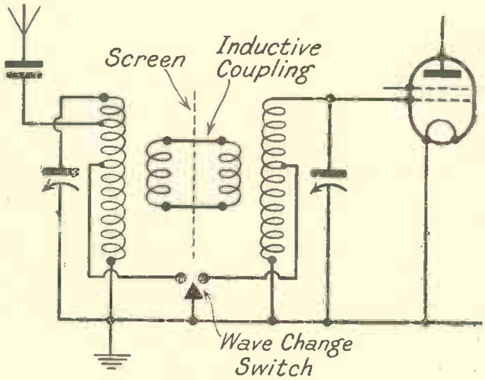


Fig. 8.—An Inductively Coupled Band Pass Filter.

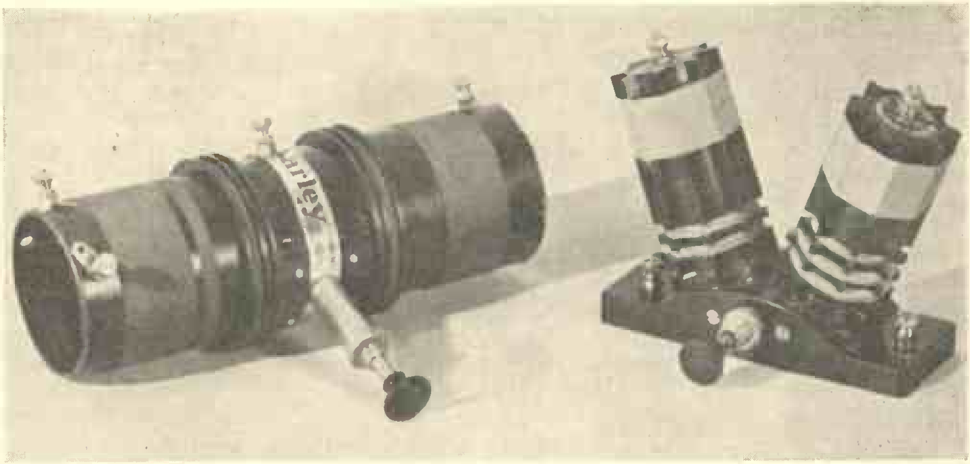


Fig. 9.—Two Examples of Band Pass Filters.
On the left is a Varley "Square Peak" type; and on the right a Lewcos Band Pass Filter.

coupling is provided by the interconnected windings, one of which is placed on each coil.

Use a Series Aerial Condenser

In using any type of band pass filter which is to be tuned by means of a gang condenser it is always advisable to connect the aerial through a small condenser, to ensure that its capacity does not upset the accurate matching of the two tuned circuits. For the same reason the reaction circuit (if employed) must be carefully designed; it is generally preferable to use a differential reaction condenser.

Tuned Grid Coupling

We will now consider the form of coupling to be used between the S.G. stages and between the last S.G. and the detector valves.

The most popular form of coupling is that known as "tuned grid." A circuit is shown in Fig. 11, from which it will be seen that the tuning coil and its associated condenser are connected in the grid circuit, a H.F. choke being inserted in the anode circuit of the preceding valve to prevent any signal currents from leaking away through the H.T. supply. The choke is as important as the coil and must have

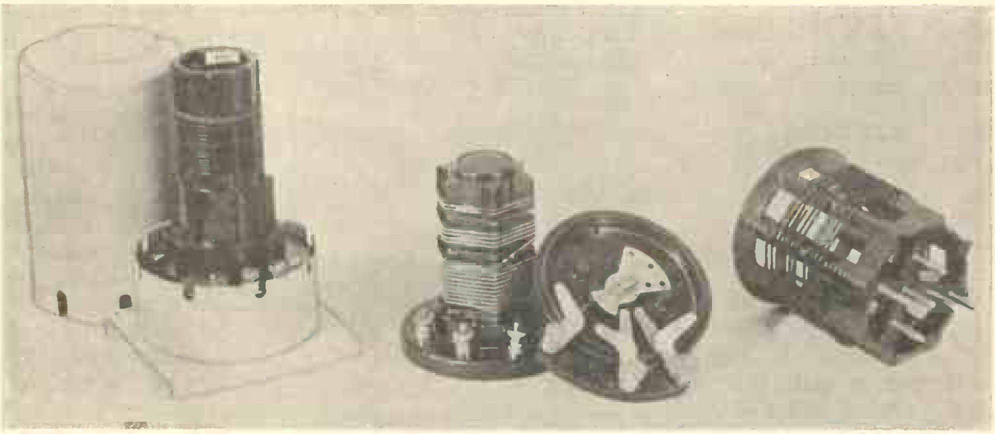


Fig. 10.—Three Examples of Short Wave Tuners.
Left, Colvern "R.S.W." two-range short wave tuner; centre, Lissen 3-range tuner with 3-way switch; right, Eddystone intervalve H.F. Transformer of the 6-pin plug-in type.

a very high inductance combined with a low self-capacity; only the very best choke should be used in this position.

The selectivity of the tuned grid coil can be improved by connecting the lead marked G in Fig. 11 to a lower tapping point or by reducing the capacity of C below its normal value of ·0003 mfd.

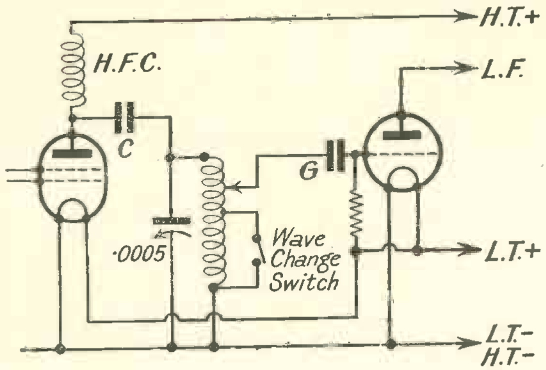


Fig. 11.—TUNED GRID COUPLING.

Tuned Anode

The tuned anode circuit is the same in principle as the tuned grid, but the coil is connected directly in the anode circuit of the previous valve, as shown in Fig. 12. The tuning condenser may be connected in either of the positions indicated by broken lines. In either case one side of the condenser is in contact with the positive high-tension lead and that is sometimes a disadvantage.

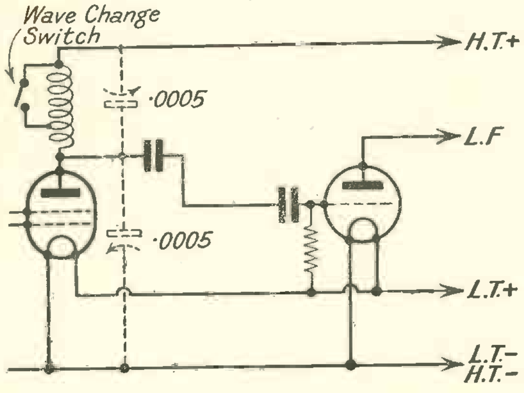


Fig. 12.—TUNED ANODE COUPLING.

H.F. Transformer

In Fig. 13 yet another system of coupling, by means of an H.F. transformer, is shown. This has all the advantages of the two systems previously dealt with, for it dispenses with the H.F. choke and also allows the tuning condenser to be kept at "earth" potential. It has a further advantage in that by reducing the number of turns in the primary winding (P) selectivity can be increased and at the same time a certain amount of voltage step-up obtained. The disadvantage of transformer coupling is that an extra winding and a rather more complicated form of wave change switch are required.

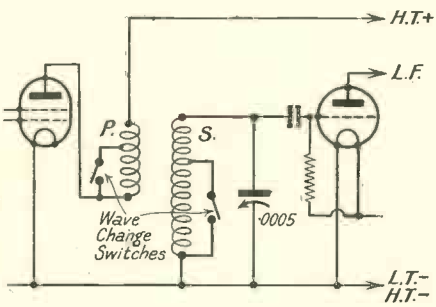


Fig. 13.—TUNED H.F. TRANSFORMER COUPLING.

Transformer coupling is most suitable for short wave S.G. receivers when the coils are of the plug-in type. It is, in fact, by far the best form of coupling for this purpose.

Reaction

A reaction winding has not been shown in Figs. 11, 12 and 13, but could be added in each case, and is provided on most commercial coils.

Makes of H.F. Coupling Coils

The same coils can be employed for both tuned anode and tuned grid circuits, and suitable ones are made by Messrs. Lewcos, Lissen, Colvern, Telsen, etc. H.F. transformers are not made by quite so many firms, but Messrs. Lewcos, Colvern and Varley list dual range coils of this type, whilst Messrs. Stratton make a range of "Eddystone" plug-in H.F. transformers specially designed for short-wave reception.

Screened Coils

In any receiver employing more than a single coil, screening is practically essential. For this reason nearly all makers now supply their coils in aluminium screening cans. A number of these are to be seen in the accompanying photographs. When using screened coils it should be remembered that the screens must be earth connected, for otherwise they cannot be truly effective.

Self-contained Switches

Of course it would be little use screening the coils if wires had to be brought out to wave-change switches, and consequently the switches associated with screened coils are generally built into the coil base.

When building a set having two or more tuning circuits the required coils can be obtained in matched sets mounted together with a ganged wave-change switch on an aluminium baseplate. Examples of these are illustrated in the accompanying photographs. Other similar sets of coils are made by Messrs. Varley, Formo, Wearite, etc.

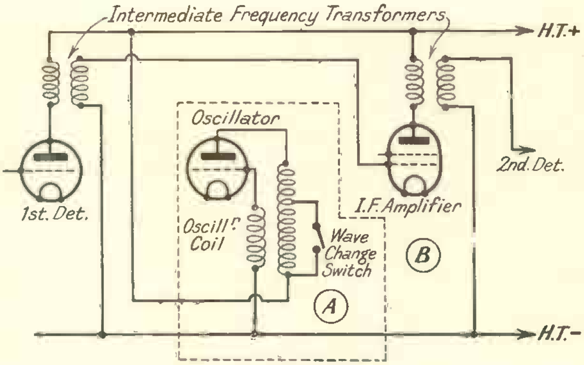


Fig. 14.—Superheterodyne Oscillator Coil and Intermediate Frequency Transformer Connections.

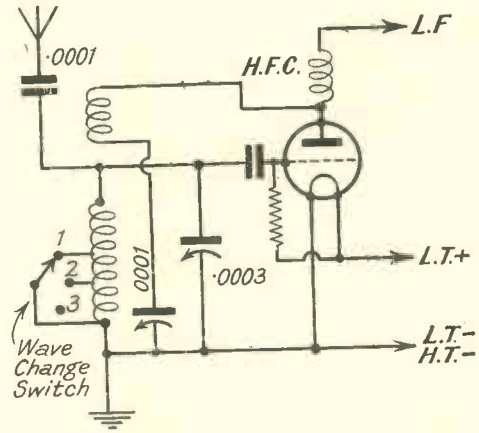


Fig. 15.—Circuit of a 3-Range S.W. Tuner.

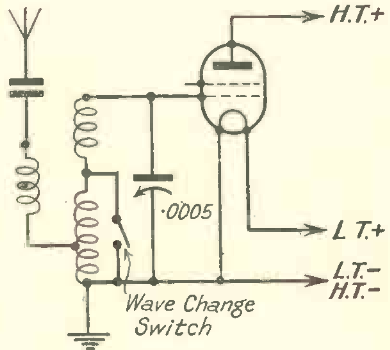


Fig. 16.—An "Anti-Breakthrough" Arrangement.

Before ordering coils which are to be tuned by a gang condenser one must make quite sure that they are all accurately matched and designed to work together because otherwise correct tuning will be an impossibility. When different coils are on hand it is well to play safe by providing each with a separate tuning condenser.

Complete Tuning Assemblies

Two or three firms, notably Messrs. Colvern and Formo, have gone even a step further by mounting the necessary coils, ganged wave-change switch and accurately matched and ganged condensers all together in one unit. This idea saves the constructor a good deal of trouble and considerably simplifies the task of building multi-valve sets.

Coils for Superheterodynes

In addition to the input filter, two other types of coils are required for a superhet receiver. These are an oscillator and two or more intermediate frequency transformers.

Oscillator coils, made by Messrs. Lewcos, Varley, Colvern and Wearite, are very similar to tuned grid coils (with reaction winding), but have a slightly lower inductance. The connections for the Colvern oscillator are shown in Fig. 14 (*a*), but other makes are wired up in a similar manner.

I.F. Transformers

Intermediate frequency transformers, which are also made by the firms mentioned above, consist of two windings inductively coupled together. Each winding is self-tuned to a frequency of 110 kilocycles (corresponding to a wavelength of about 2,700 metres) and the unit provides band pass coupling between the first detector and intermediate frequency amplifier as well as between separate I.F. stages. The circuit arrangement is shown at (*b*) in Fig. 14.

Special Coils

Just recently a number of what might be called " special " coils have come on to the market.

Perhaps the most prominent of these is the short-wave coil, which has one or two tappings so that it may cover a tuning range of from about 15 to 80 metres when used in conjunction with a suitable wave-change switch. In this class we have the Lissen and R.I. unscreened coils and the Colvern KSW, which, like the broadcast coils, is enclosed in a screening can.

The circuit of all the short-wave coils is similar to that of Fig. 15.

Preventing M.W. " Breakthrough "

Another kind of coil which has been developed to meet the needs of present-day broadcast conditions is the Lissen type A. A circuit of this coil is given in Fig. 16, from which it will be seen that an aperiodic aerial winding is used, but instead of being connected at its lower end of earth it is joined to a tapping on the long-wave portion of the tuned grid winding. By this arrangement the possibility of the transmission from a powerful nearby medium wave transmitter " breaking through " on the long wave band is considerably reduced.

The same firm has also introduced an " anti-breakthrough " choke which can be used with coils of the ordinary type to produce the same result. The choke is merely connected in series with the aerial lead, and its inductance is of such a value that the choke acts as a barrier to wavelengths below about 600 metres. The choke must, of course, be short-circuited for medium wave reception.

In the above " rapid review " of contemporary coils it has been impossible to mention every type and make by name, but it is hoped that sufficient has been said to enable the reader to make an intelligent choice of the coils suitable for his own requirements.

HOW TO MAKE AN AUTO TIME SWITCH

TO START AND STOP A WIRELESS SET AUTOMATICALLY

By EDWARD W. HOBBS, A.I.N.A.

THE modern style clock in light oak with ebonized edges, shown in Fig. 1, not only tells the time but will automatically switch on the wireless at any predetermined time and will switch it off again at any required moment.

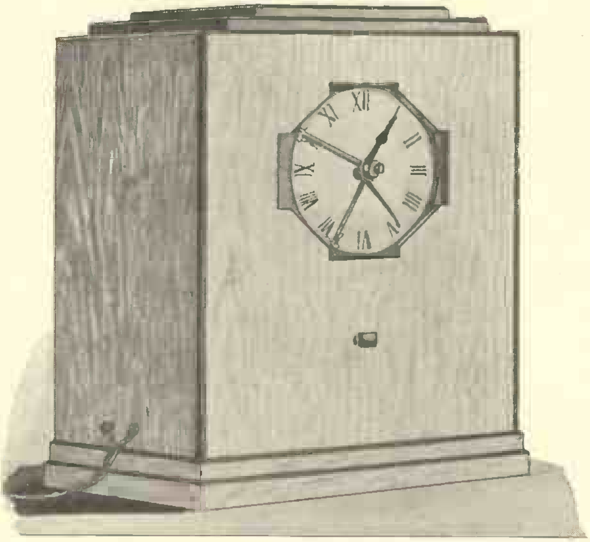


Fig. 1.—THE COMPLETED AUTO TIME SWITCH.

How it Works

The device consists of an ordinary clock, mounted in a special case and having two adjustable contacts which can be placed at any positions in front of the clock dial in such a way that the hour hand of the clock engages one of them and by closing a local battery circuit actuates a relay or magnetic switch which closes the L.T. circuit of the wireless set and starts it playing. The second contact is used to actuate the relay a second time and thereby to open the circuit and switch off the wireless set.

The adjustable contacts are so arranged that current does not flow through the clock—the hour hand merely lifts a very light trigger which makes contact with a slip ring disposed around the outer edge of the dial but not connected to it electrically.

Materials and Parts

The following comprise the essential parts and materials for the complete auto-time switch, but stock parts of other makes can be substituted if approximately the same size.

1 clock mechanism and dial about 5 inches diameter.
2 bell magnet bobbins about $2\frac{1}{2}$ inches long, 1 inch diameter.
4 ozs. No. 26 D.C.C. wire ("*Lewcos*").
2 1·5 volts dry batteries, No. B.9 ("*Drydex*").
6 yards twin flexible lighting wire ("*Lewcos*").
8 small terminals ("*Belling Lee*").
1 piece soft iron $\frac{1}{2}$ inch wide, $\frac{1}{4}$ inch thick, $2\frac{3}{4}$ inch long.
1 piece brass strip $\frac{3}{4}$ inch wide, $\frac{1}{16}$ inch thick, 6 inches long.

Wood for Case

2 *sides*, 4 by $11\frac{3}{4}$ by $\frac{1}{4}$ inch.
1 *front*, 9 by $11\frac{3}{4}$ by $\frac{1}{4}$ inch.
1 *top*, $4\frac{1}{4}$ by $9\frac{1}{2}$ by $\frac{1}{4}$ inch.
1 *pediment*, $7\frac{1}{2}$ by 4 by $\frac{1}{4}$ inch.
1 *cap*, 6 by $3\frac{3}{4}$ by $\frac{1}{4}$ inch.
Plinth. 1 $9\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{3}{16}$ inch.
,, 1 10 by $\frac{3}{4}$ by $\frac{3}{16}$ inch.
,, 2 $4\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{3}{16}$ inch.
,, 2 $4\frac{3}{4}$ by $\frac{3}{4}$ by $\frac{3}{16}$ inch.

Door. 8½ by 11 by ¼ inch.
Bottom. 8½ by 4 by ¼ inch.
2 *partitions*, 4 by 3 by $\frac{3}{16}$ inch.
Backboard for slip rings, 7 inches square, ½ inch thick.

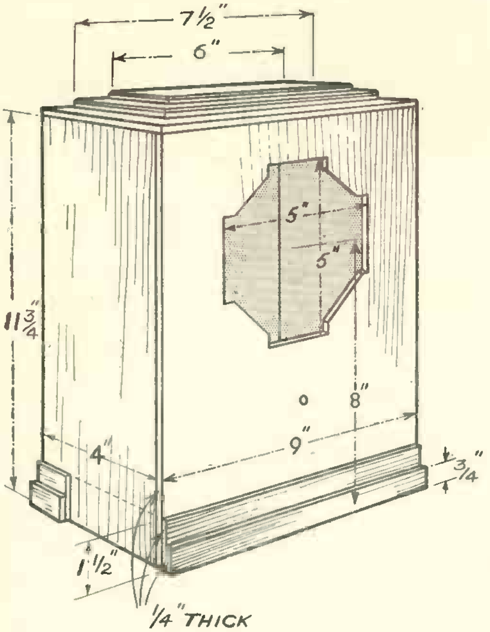


Fig. 2.—Details and Dimensions of the Case.

Sundries

- 1 piece hard springy brass strip, ⅛ inch wide, $\frac{1}{32}$ inch thick, 18 inches long.
- 1 piece hard drawn brass spring wire, No. 32 gauge, 36 inches long.
- 1 piece soft brass wire, No. 16 gauge, 6 feet long.
- 1 piece ebonite, ⅜ inch thick, ⅝ inch wide, ¾ inch long.
- 1 piece ebonite, ½ inch thick, 1½ inches wide, 1½ inches long.

Sundry small screws and nails, 1 pair small brass hinges, 1 piece sheet glass, 6 inches square, 1 small on-off switch.

Making the Case

Details and sizes of the parts for the case are given in Fig. 2 and are suitable for a clock of the common alarum type, about 5 inches in diameter, but if any other size clock is used the diameter of the front opening must be altered to correspond with that of the clock dial.

Prepare the various pieces for the case, then glue and pin them together, fit the internal compartments as shown in Fig. 3, and prepare and hinge the back. Clean down the exterior with fine sandpaper, then stain and polish it in any desired colours.

Fit two terminals for the connections to the wireless set through the bottom of the case, but if the set is mains operated, be careful to substitute a shielded plug and socket connection and to well insulate it by mounting it upon an ebonite block. Ordinary terminals fitted through the bottom board or side of the case are quite satisfactory for battery operated sets.

Magnetic Switch

The magnetic relay switch—shown complete in Fig. 5—consists of a substantial wooden base and frame, on which are mounted two separate electro-magnets, and above them a segmental switch comprising a shaped iron pole piece mounted to turn freely in brass bearings clamped to the top of the magnet bobbins.

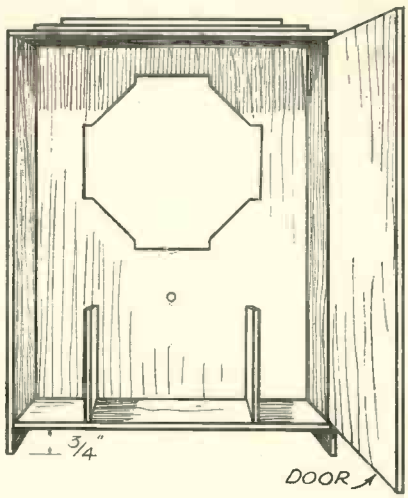


Fig. 3.—Back View of Case with Internal Compartments.

A segmental block of ebonite is screwed to the top of the pole piece and a brass contact strip is embedded in its surface. Two insulated brushes are disposed above the switch in such a manner that when the switch is turned to the right both brushes bear upon the contact strip, but when the switch is turned to the left the contact strip is moved from beneath the brushes and they then bear on the ebonite block.

Action of Magnets

The action of the magnetic switch is very simple but effective; suppose the switch is "off"—that is the segmental switch is to the left. At the predetermined time, the clock closes the local battery circuit, which then energises the magnet to the right of the switch and the magnetic attraction causes the switch to turn towards it, thus bringing the contact strip under the pair of brushes and so closing the L.T. circuit in the receiving set.

Current only flows through the local battery circuit for a minute or so while the clock hand passes the trigger contact; thereafter no current flows through the local circuit until the hand passes the second trigger contact, which thereupon closes a local circuit through the second magnet, which attracts the segmental switch and turns it back to the "off" position.

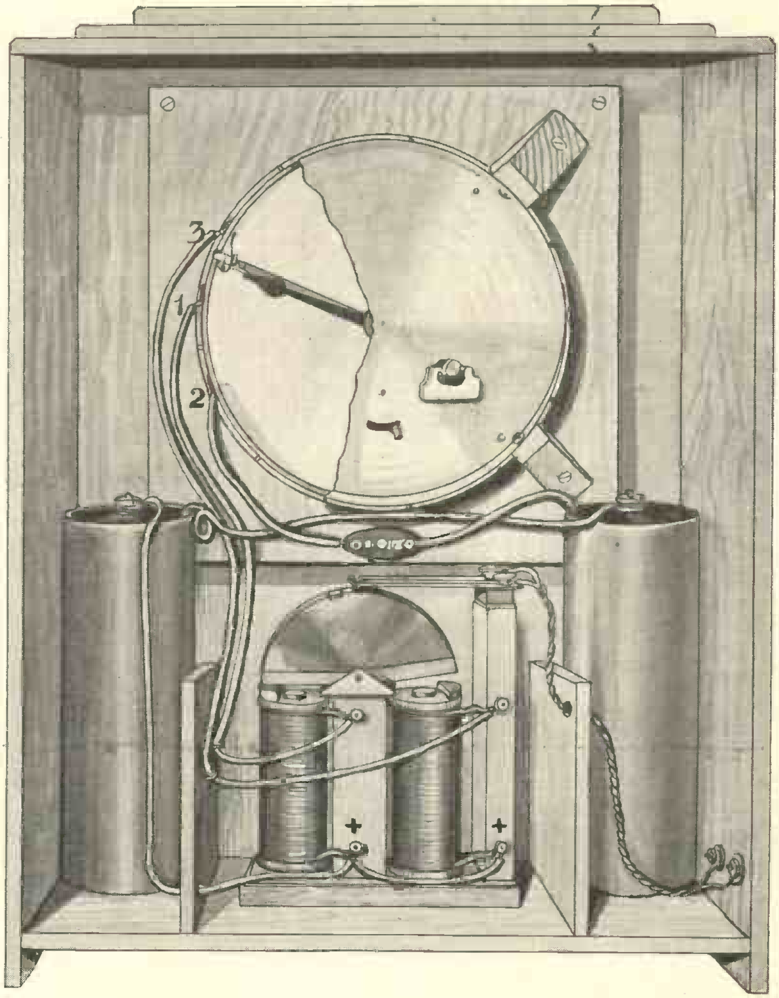


Fig. 4.—Uni-view Wiring Diagram of the Auto Time Switch.

Winding and Mounting the Magnets

Wind each bobbin with No. 26 D.C.C. wire, using as much as is necessary to fill the bobbin uniformly, about 2 ozs. will be sufficient on each, but wind equal amounts on each and in the same direction.

Next mount each bobbin vertically on a stout wood base, place the bobbins 2 inches apart and fasten each down very firmly, as shown in Fig. 5, by a clamping screw into the iron core.

Prepare and fix a block of wood about 1 inch wide and $\frac{7}{8}$ inch thick, between the magnets and of such height that the top of the wood is just below the tops of the bobbins.

Fix another wooden upright close behind the second bobbin, making this upright $3\frac{1}{2}$ inches high above the top surface of base and about $\frac{5}{8}$ inch thick and 1 inch wide.

The Armature

The pole piece or armature with its

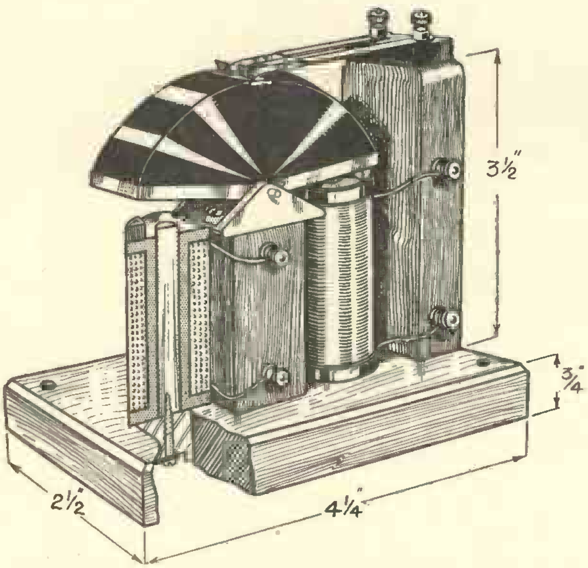


Fig. 5.—DETAILS OF THE MAGNETIC RELAY SWITCH.

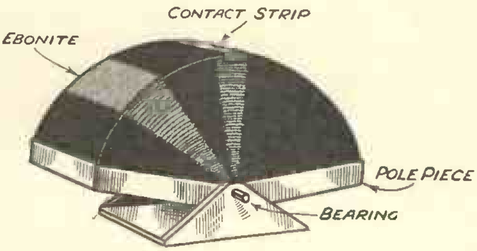


Fig. 6.—DETAIL OF ARMATURE AND BEARING.

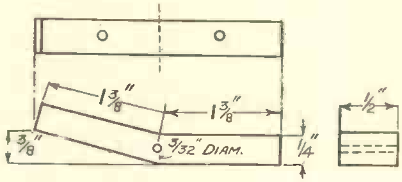


Fig. 7.—DETAIL OF THE POLE PIECE OF THE AUTO TIME SWITCH.

bearing block and the ebonite segment is shown assembled in Fig. 6. The whole is screwed to the top of the block between the magnets.

The pole piece is shown in Fig. 7, the bearing in Fig. 8 and the segment and contact strip in Fig. 9. Bend the iron to shape for the pole piece, then drill the bearing hole, shape the ebonite block, fit the contact strip and screw the ebonite to the top of the pole piece.

Make the bearing block from strip brass soldered together and provide a hard steel pin to act as a pivot. Screw the bearing in place, put the pole piece between the ears of the bearing and push the pivot pin through the bearing holes.

Fit little blocks of ebonite to the tops of the bobbins so that the pole piece cannot strike the iron core but stops about $\frac{1}{32}$ inch away from it.

Test the action by connecting first one and then the other magnet windings to the dry battery. The switch should move over sharply and decidedly in either direction; see that the switch turns easily, without frictional losses, but absolutely without shake or sloppiness.

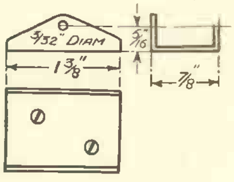


Fig. 8.—DETAIL OF BEARING.

Brush Gear

Bend up the springy brass contacts—as shown in Fig. 10—mount them on an ebonite block and screw them to the top of the upright behind the magnets.

Fit shorter strips above the contacts to increase their springiness, then adjust them so that they bear evenly and firmly—but without too much pressure on the ebonite segment and also adjust them so that they make contact with the cross strip, as already described.

Fix the terminals for the various connecting wires, then test the action again and if all is correct mount the switch centrally on the bottom of the clock case.

Pre-set Contacts

There are two separate and insulated pre-set contacts which consist of thin ebonite fingers or arms with rocking or trigger contacts and a fixed contact on their outer ends. The inner ends of the fingers are bushed, as shown in Fig. 11, and the whole mounted in a hole in

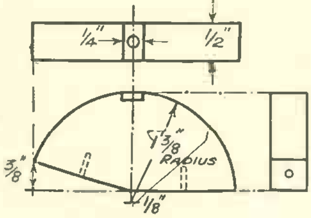


Fig. 9.—THE SEGMENT AND CONTACT STRIP.

the centre of a glass plate. The whole arrangement will quickly be realised by a glance at Fig. 11, which shows the pre-set contacts and a part of a slip ring in place.

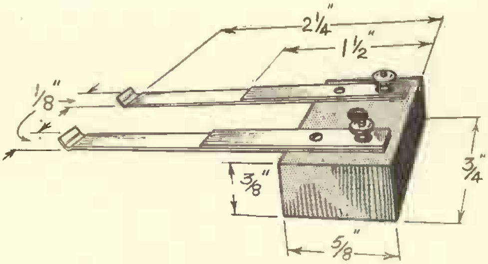


Fig. 10.—DETAILS OF THE BRUSH GEAR.

Action of Contacts

Prepare three brass wire rings about 5 inches diameter, solder a 2 foot-length of insulated flexible wire to each ring, then mount them in the aperture in a square piece of wood about ½ inch thick, spacing the wire rings about ⅛ inch away from the wood on short brass pegs driven into the wood, as shown in Fig. 12. Solder the rings to the pegs. Take care to make the rings as nearly circular as possible and see that they can lay flat on the table before fixing them.

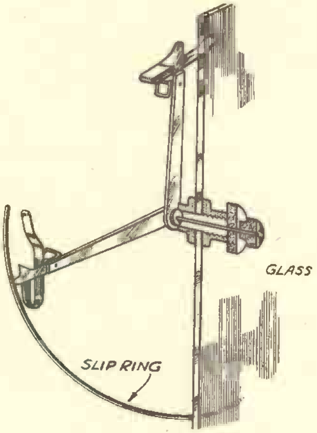


Fig. 11.—THE PRE-SET CONTACTS.

Now make up the two fingers and bushes as shown separately in Fig. 13, cut a hole through the centre of the glass plate, fit an ebonite bush to it, as shown in Fig. 11, then adjust the fingers so that the brass contacts at the ends bear upon the side of the centre wire remote from the glass.

Bend the trigger contacts to shape as shown in Fig. 14, and mount one on each finger, then bend the flat contact pieces to shape, fix them by a rivet to a little block of ebonite and adjust them while in place. The flat contact must just clear the slip ring, the trigger must hang free but not sway about, there must be space enough between it and the finger to allow the minute hand to pass without touching.

When the trigger is pushed forward it should raise the spring contact and press it against the slip ring. The whole must work perfectly easily and the flat spring must be very thin, springy and very easy to move.

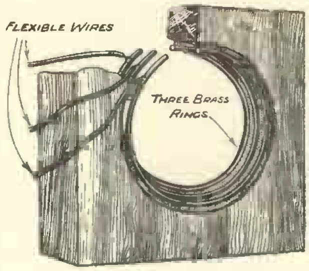


Fig. 12.—DETAILS OF THE SLIP RINGS.

Fixing the Contact Plates

Fasten the wooden plate with the slip rings and the glass with the contact fingers complete, to the inside of the case, then mount the clock behind it, taking great care to have the main spindle of the clock exactly in line with the centre of the finger spindle.

Secure the clock with metal or wooden brackets screwed to the case, generally as shown in Fig. 15, arranging the details to suit the particular timepiece.

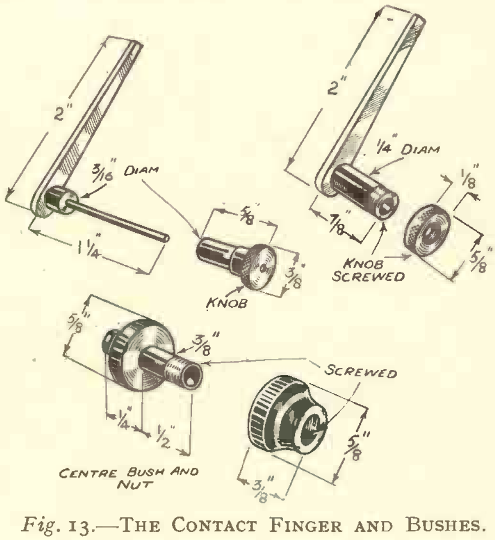


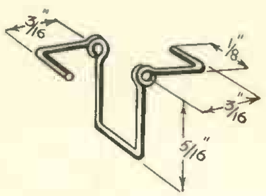
Fig. 13.—THE CONTACT FINGER AND BUSHES.

Connect up the batteries and switches according to the circuit diagram (Fig. 16), and the uni-view diagram (Fig. 4), then adjust the triggers—if necessary—so that the minute hand clears them, but the hour hand of the clock just pushes the trigger forward enough to press the spring contact against the outer slip ring. Only very light pressure is needed; it must, in any case, not be heavy enough to stop the clock.

Connections to Wireless Set

Connect the flexible wiring to the switch terminals on the clock case, or to the plug connecter, as the case may be, and connect the other ends of the flexible wires, one to each contact of the L.T. switch.

Arranged in this way, the set can be switched on or off at will in the usual way and without alteration the auto-time switch will automatically switch the set on or off, provided the switch on the wireless set is left in the off position.



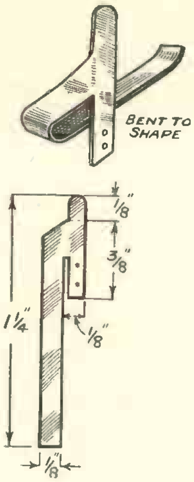


Fig. 14.—The Trigger and Contact Springs.

This shows how the trigger and contacts should be bent to shape. Mount one on each finger, then bend the flat contact pieces to shape, fix them by a rivet to a little block of ebonite and adjust them while in place. The flat contact must just clear the slip ring and the trigger must hang free but not sway about.

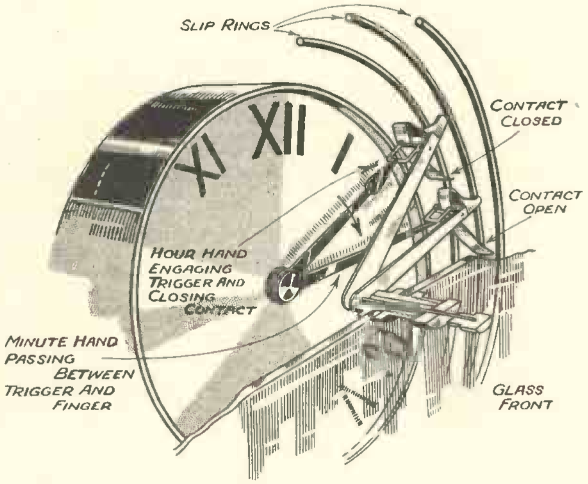


Fig. 15.—How the Fingers, Trigger and Contacts are Assembled.

The details should be arranged to suit the particular timepiece which is being used.

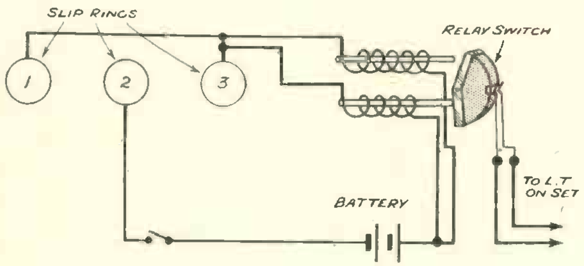


Fig. 16.—The Circuit Diagram of the Auto Time Switch.

A simple on-off switch is provided in the clock case to cut off the local battery current whenever the automatic control is not required.

In conclusion, it may be pointed out that not only is this device a convenience by switching on a particular programme, but it is a useful safeguard should the premises be left unoccupied, as the set can be arranged to start and stop playing, and thus give a semblance of habitation of the premises, and baffle would-be intruders.

It is a good idea to stain the exterior of the auto time switch to match the receiver so that it can be placed on or near the set, and not look too conspicuous.

REMOTE CONTROL SYSTEMS

By EDWARD W. HOBBS, A.I.N.A. and H. E. J. BUTLER

A REMOTE control is a device which enables a wireless set to be worked from a distance without having to touch it. Obviously the ideal scheme is one which enables the set to be tuned and varied in volume, but such a device is practically unobtainable, although the steady reduction in the number of controls on the average receiver brings its realisation nearer.

Simplest Form of Control

The simplest method of controlling a set from a distance is to run a pair of extension wires from the L.T. on-off switch in the set to a simple tumbler type lighting switch at any convenient place. Fig. 1 shows the essentials of such a scheme; it is quite easy to install and is often a very real convenience in the home, especially when a powerful set is installed.

If the switch is to be placed on the wall, a flush-pattern can be used if the casing is embedded in the plaster, and best quality lead covered twin lighting cable should be used. This can be set in a chase or groove cut in the plaster and embedded therein by filling in the chase with moist plaster-of-paris or Keen's cement.

In most cases it is desirable to take the trouble to conceal the wire in this way; the wallpaper can easily be repaired by pasting a torn strip of the same paper over it; do not cut the strip, as this makes it more conspicuous; the irregular edges of the torn strip will be practically invisible.

Use of Flexible Wire

The leads to the set are connected on to each side of the switch; that is, one wire goes to one terminal and the second wire to the other terminal, thus putting the second switch in parallel with the first.

If it is desired to control the set from any part of the room, a pear switch—such as that shown in Fig. 2—should be used, and be connected as before, but by means of a suitable length—say 4 yards—of good quality 5-amp. twin lighting flexible.

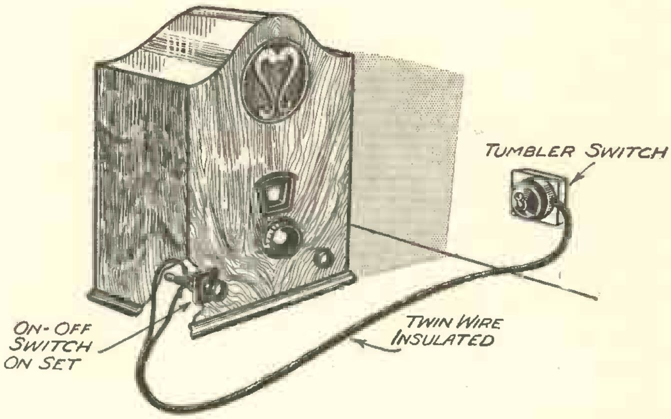


Fig. 1.—SCHEMATIC ARRANGEMENT OF SIMPLE REMOTE CONTROL.

A pair of insulated wires are connected to the on-off switch in the set and taken to a tumbler or other switch at any convenient position.

The most obvious limitation to this scheme is that the set can be controlled separately by either switch, but there are combinations of switch positions which prevent full control by either. For example, when the set switch is "off" the remote control can switch the set on or off as desired, but if the set switch is "on," the remote control cannot switch it off, but in practice this defect does not prove so objectionable as it appears.

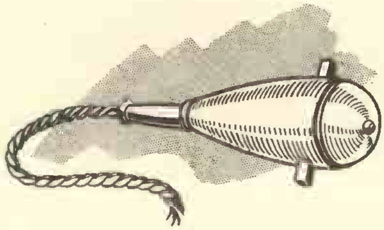


Fig. 2.—Pear Switch.

This type of switch is preferable when flexible wire leads are used.

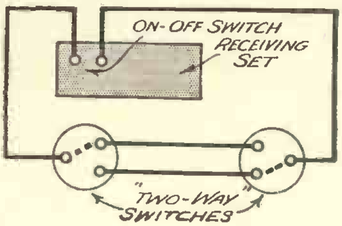


Fig. 3.—Dual Control of Set.

This circuit shows how a receiver can be switched on or off at will from either of two separate positions.

Independent Control from Two Places

Full dual control can be obtained in several ways; one of the simplest is to use standard "two-way" switches in place of the simple on-off type.

This necessitates removing the on-off switch from the set, or fixing it in the "off" position, the latter being the simplest, and avoids interference with the set wiring.

The next step is to place the two "two-way" switches in the desired places; for example, the first on or near the set, the second in another room.

Then connect one wire from one terminal of the on-off set switch to the first "two-way" switch.

Connect another wire from the second terminal of the on-off set switch to the second "two-way" switch; then connect both "two-way" switches with a pair of wires.

Inspection of the two-way switch will reveal the fact that there are three contact terminals, one connects to the movable switch contact which is marked by the knob or handle, the others connect respectively to the fixed contacts which are alternately engaged by the switch arm. The single wire goes to the single or switch-arm contact, the pair of wires go to the other contacts.

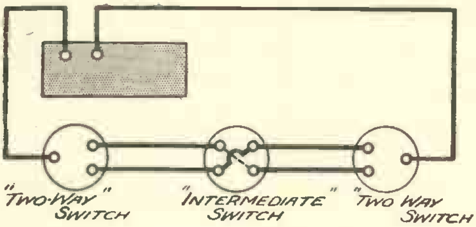


Fig. 4.—Multiple Control.

By adding one or more "intermediate" switches to the circuit given in Fig. 3 the set can be controlled from any desired number of places.

The circuit will now be as shown diagrammatically in Fig. 3, and it will be seen that no matter how the "two-way" switches are operated, either of them can be used to switch the set on or off without regard to the other, thus giving full dual control.

Multiple Control

Control from three or more positions can be obtained by adding one or more "intermediate" switches in the parallel wires which connect the two "two-way" switches in the previous circuit. The intermediate switch has four contact terminals, these are connected by wires in the form of the letter X, as shown dotted in Fig. 4, unless such connections are incorporated in the particular switch.

The pairs of wires

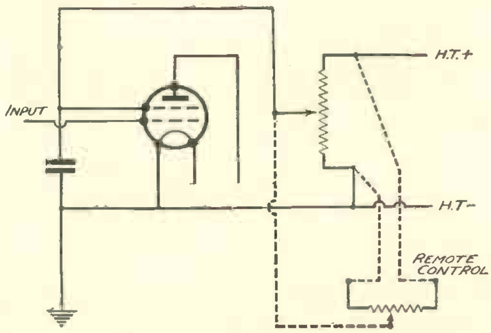


Fig. 5.—Undesirable System of Remote Control.

In this skeleton circuit long H.T. leads introduce objectionable features—loss of power and a tendency to instability.

are then connected to the pairs of terminals on opposite sides of the switch—as shown in Fig. 4; the switch arm connects either the upper or the lower of the parallel wires, according to which way it is set.

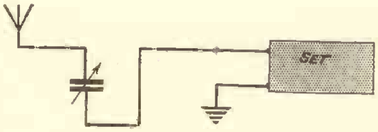


Fig. 6.—Remote Control of Input.

A low-value variable condenser is inserted in series in the aerial lead-in wire.

General Precautions

On a battery-driven set, the stock patterns of "miniature" switches are quite suitable, as the switch has only to handle a low voltage, but on a "mains" set it is best to be on the safe side and to use standard 5-amp. lighting fittings, and treat the job as an extension of the lighting system. In either case the wiring must not be incorporated in any way directly or indirectly with the house lighting system.

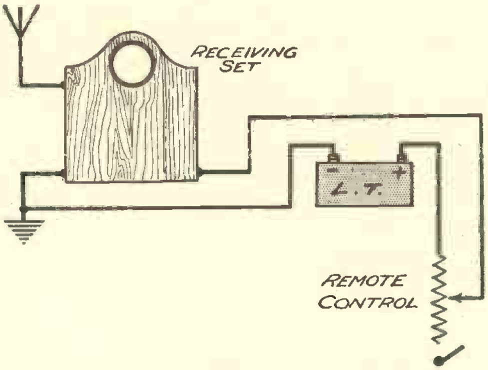


Fig. 7.—Filament Voltage Control.

A rheostat connected in series in the L.T. lead from battery to set enables a control of volume as well as a switch control. The value of the rheostat should be 30 or 40 ohms. This arrangement is rather harsh in action.

Remote Control of Volume

The basic principle of the generally used forms of remote-control devices which regulate the volume of sound from the loud speaker comprise extension leads from the appropriate part of the receiver circuit to a potentiometer or variable resistance —with or without variable capacity— mounted on a small table stand or wall plate.

Some receivers, notably the H.M.V. series of mains sets and radiogramophones are provided with sockets or connections for a remote volume control, hence with such instruments it is only necessary to acquire the remote control unit and plug it into the set.

There are so many different methods and combinations of systems of volume control in receiving sets that it is impracticable here to give details for each; in most cases the method is the same. Extension wires are taken from the appropriate elements on the set and connected to similar elements located in a small cabinet or table stand of some kind.

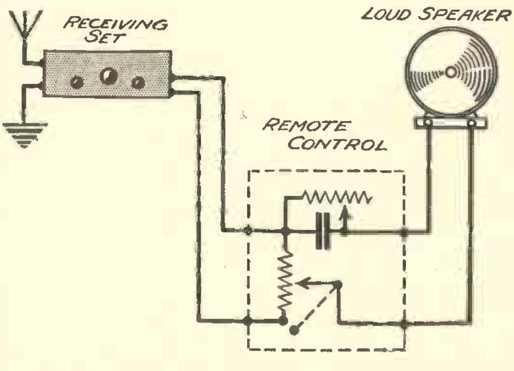


Fig. 8.—Independent Loud-speaker Control.

A loud-speaker volume control using a 10,000 ohm resistance across an 0.1 mfd. condenser with on-off switch.

Things to Avoid

There are numerous points that must be considered before fitting extension wires to volume control systems that are built in a set; for example, in Fig. 5, the fitting of extension leads to a potentiometer in parallel introduce objectionable features, such as long parallel wires carrying H.T. current, with unwanted capacities to earth, and almost uncontrollable hand-capacity effects. Much the same thing happens if the control is in the grid circuit, hence it is preferable to concentrate attention either on pre-detector remote controls, or those chiefly concerned with the output circuit unless the set has been designed for remote control or is readily adaptable to the purpose.

Input Control

An effective plan that controls volume with some success and has only minor disadvantages is to insert a low-value condenser in series in the aerial lead-in wire—as shown in Fig. 6—and house the condenser in a neat wooden case.

Keep the aerial leads as short as possible, and when practicable run them around a picture rail or in any manner by which they can be kept away from the walls.

Another very effective plan for use with battery-operated sets is to control the voltage of the filament current as suggested in Fig. 7, by taking a lead from the L.T. plus side of the battery to a 30- or 40-ohm rheostat—which forms the remote controller—thence take another wire back to the L.T. plus terminal on the set. This arrangement controls the filament voltage of all the valves, is rather harsh in action, and in some cases may adversely affect the tone. By using a rheostat with an "off" position the device can be used to regulate volume and to stop or start the set.

Output Control

When an external loud speaker is used it can be controlled readily from a distance by several means. By using wall plugs and jacks, such as those made by Igranic and Bulgin, an external circuit of any reasonable length can be used and the speaker plugged into it at any desired point; this acts as an on-off switch. Complete remote control of the speaker can be had by a compact device comprising a local circuit shunted across the loud speaker and suitably connected by long leads.

In the circuit of Fig. 8, a combined volume control, tone corrector and switch provide full control over the speaker.

Mechanical Controls

Those who are mechanically minded may well experiment with some such scheme as that suggested in Fig. 9—which makes use of a development of the drum-dial idea. The essentials of the scheme comprise a return spring, which turns the tuning drum, dial or knob, as the case may be, to zero.

A waxed cord is wound around a drum attached to the spindle, and this cord is connected to a Bowden wire and cable, which is taken to the remote control station, where it is moved as required by means of a lever or drum. The drum spindle must have a friction disc or washer on it to prevent the tension of the return spring moving it.

Such a scheme, in combination with the tone and volume control circuit in Fig. 8, admits of the complete control of a wireless set from a distance, as it enables the set to be tuned and regulated for tone and volume.

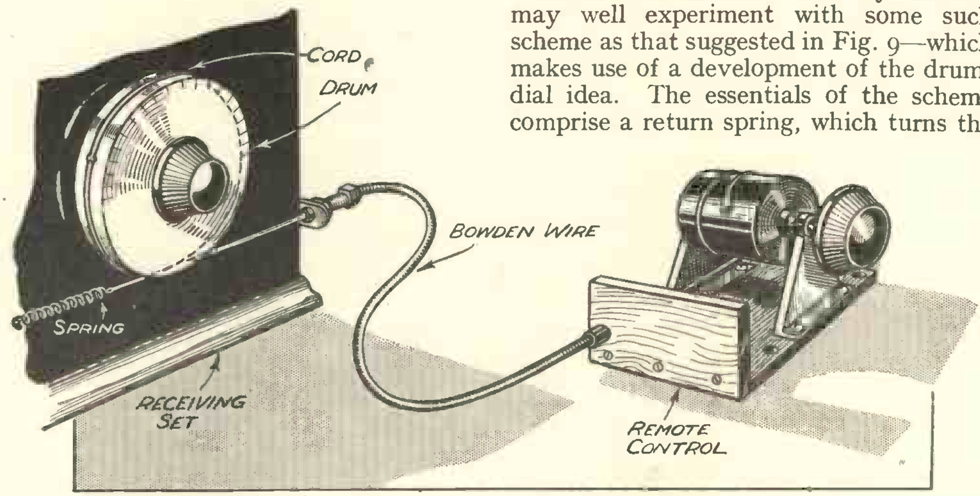


Fig. 9.—MECHANICAL CONTROL.
This schematic diagram shows how a wireless set can be tuned from a distance.

REMOTE CONTROL USING A RELAY

How a Relay Works

AN electro-magnetic relay consists essentially of an electro-magnet having an armature which actuates one or more pairs of contacts when a current is passed through its coil. The source of current for the operation of the relay may be the same as that which supplies the main circuit, or it may be independent. Fig. 10 shows a Western-Electric relay with one pair of contacts. (This type of relay may be adapted for two or three pairs of contacts when the circuit conditions require it.) When a current is passed through the coil the armature is attracted towards the L-shaped yoke, and the ebonite stud, which is fixed on the armature, raises the lower contact and closes the circuit between the contacts. A brass or nickel pip is riveted in the air gap part of the armature to prevent actual contact between the armature and the yoke. If this is not done, the armature would stick to the yoke after the current in the coil ceased. If it is desired to break a circuit by the operation of a relay, the ebonite stud of the armature passes through a hole in the lower contact and operates the upper one. This is illustrated by the Siemens relay in Fig. 11.

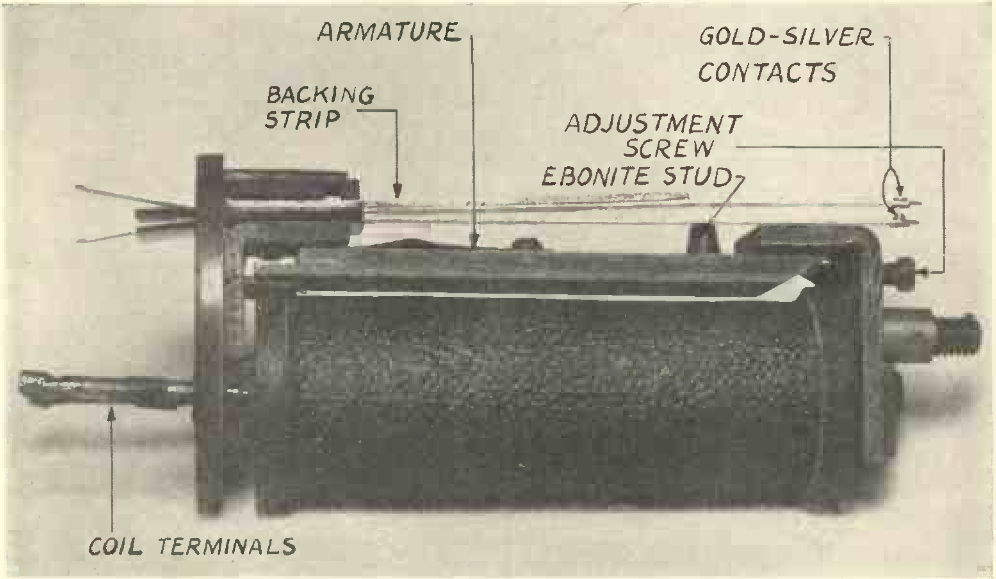


Fig. 10.—A WESTERN-ELECTRIC TYPE OF RELAY.
Adapted for use in remote control circuits shown in Figs. 18 and 20.

Power to Operate

The power required to operate a relay depends on the design, and also the number of contacts which have to be operated. A relay may work on 4 volts 5 milliamperes without any contacts, but would require from 7 to 10 milliamperes with one pair of contacts and from 12 to 15 milliamperes with two pairs of contacts. The resistance of the coil is therefore proportioned to give the necessary power for the required conditions. The resistance of a relay to work on 4 volts will therefore lie between 250 and 400 ohms, and the power required to hold the relay closed will be 0·04 to 0·06 watt. The addition of a relay to a three-valve battery set will therefore make only an extra 5 per cent. demand on the low tension battery at the most.

Types of Relays

Three types of relays suitable for the remote control of wireless sets are shown

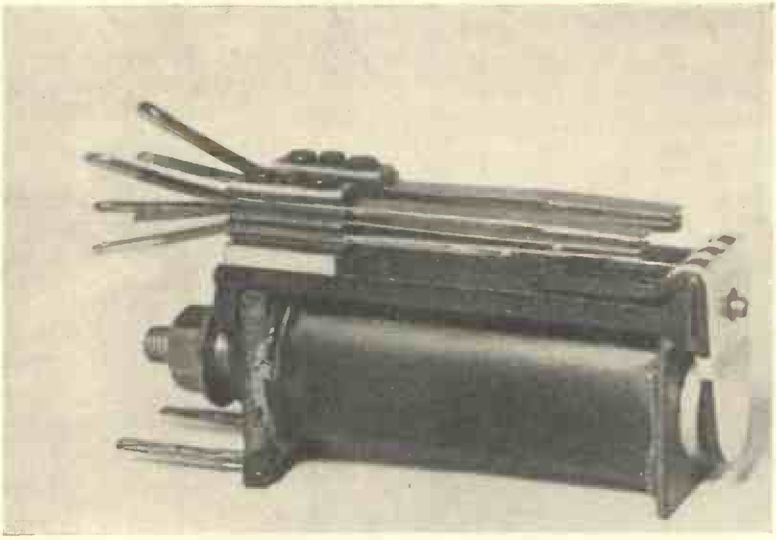


Fig. 11.—A SIEMENS TYPE OF RELAY.

With two sets of contacts suitable for the remote control of an eliminator and accumulator set. The relay may be conveniently mounted on an angle bracket by means of the nut shown. This relay may be adapted for single-circuit switching by screwing one set of contacts in the middle of the contact base and removing the other set.

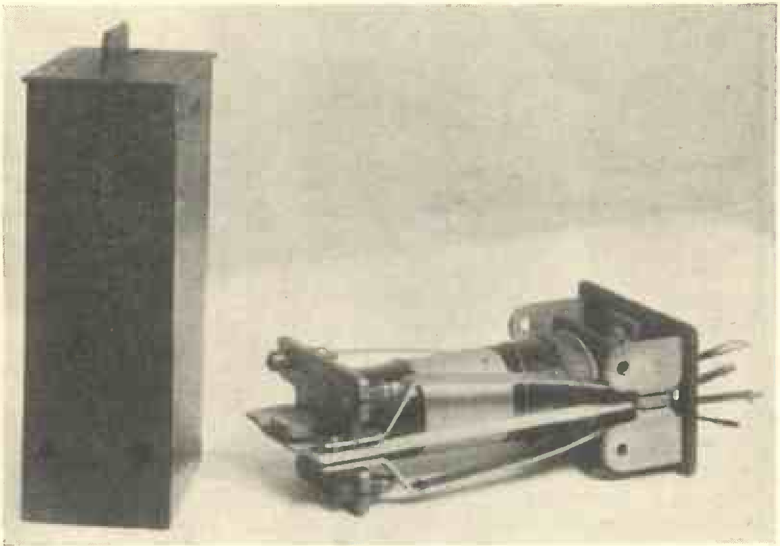


Fig. 12.—A SENSITIVE TYPE OF RELAY WITH COVER.

Suitable for the remote control of all-battery set only, as the armature forms part of the electrical circuit. The armature itself forms the movable blade which is attached to the yoke of the magnet by thin flat steel springs to give the required flexibility. Three adjusting screws are provided.

in Figs. 10, 11 and 12. They are all of efficient design and are used chiefly for telephone exchange apparatus where reliability is essential. The type shown in Fig. 10 has the advantage that the sensitiveness can be adjusted very easily by means of a pointed screw which regulates the length of the air gap when the armature is at rest. This screw must be non-magnetic.

The relay shown in Fig. 11 may be adapted for single-circuit switching by screwing one set of contacts in the middle of the contact base and removing the other set. This relay has an L-shaped armature pivoted on a knife-edge which is formed at the end of the yoke. A small brass stud projecting through the armature prevents the armature becoming dislodged from its knife-edge. This type has the advantage that the armature is balanced and there is no power expended in lifting the dead weight of the armature.

Fig. 12 shows an American type of relay which is suitable for switching one circuit only. The armature itself forms the movable blade which is attached to the yoke of the magnet by thin flat steel springs to give the required flexibility. Three adjusting screws are provided. The two adjusting screws which bear on the contacts have hard-wood ends so as to insulate them from the frame. The lower screw regulates the distance of the armature from the pole piece and the upper one gives the best spacing for the contacts. The spring on the opposite side to the contacts balances the pull on the armature. This type of relay is very sensitive owing to the lightness of the armature, but has the disadvantage that the frame and case is live because the armature forms part of the electrical circuit.

WINDING A RELAY BOBBIN

Size of Wire

Although the correct gauge of wire for a relay coil may be arrived at by calculation it is best determined experimentally. The resistance of the bobbin, when wound, may be determined by multiplying the winding volume by the ohms per cubic inch for the size of wire to be used. As an example, consider the relay bobbin shown in Fig. 13. The diameter of the core when insulated is $\frac{3}{8}$ in. and the outside diameter of the coil, allowing for inter-layer insulation, is $\frac{7}{8}$ in. The length of the winding between the cheeks is $2\frac{3}{8}$ in.

∴ Volume of winding

$$= 3\tfrac{1}{7}\,\frac{(\frac{7}{8})^2}{4} - \frac{(\frac{3}{8})^2}{4} \times 2\tfrac{3}{8} \text{ cub. in.}$$

$$= 3\tfrac{1}{7} \times 2\tfrac{3}{8}\,\frac{(\frac{7}{8}+\frac{3}{8})\,(\frac{7}{8}-\frac{3}{8})}{4} \text{cub. in.}$$

$$= 3\tfrac{1}{7} \times 2\tfrac{3}{8} \times 1\tfrac{1}{4} \times \tfrac{1}{2} \times \tfrac{1}{4} \text{ cub. in.}$$

$$= 1{\cdot}17 \text{ cub. in.}$$

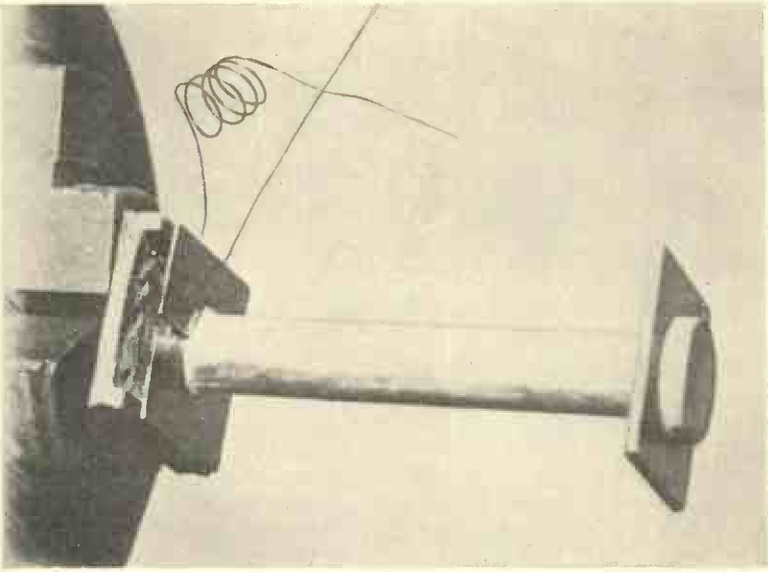


Fig. 13.—MAKING YOUR OWN RELAY.

Notice that the core is insulated with waxed paper ready to receive the winding.

This figure, owing to irregularities in the winding, will be high, so that 1 cubic inch of winding may be counted on. Thus the above coil wound with 37 S.W.G. enamel-covered wire would have a resistance of about 300 ohms and with 36 S.W.G. enamel-covered wire would give 200 ohms.

Enamel-covered wire gives the most efficient electro-magnet because more turns can be accommodated for a given resistance.

Insulating the Core

The Swedish iron core of the magnet is insulated with waxed paper or empire cloth before the wire is put on. This should be cut just a fraction longer than the winding space so that there is no possibility of the end turns touching the core. Fig. 13 shows the bobbin, with waxed paper on the core, ready for winding.

Starting the Winding

Unless the ends of the winding are to be connected to tags fixed on one of the end-cheeks, it is necessary to terminate the coil with short pieces of flexible wire. These are made by starting the winding with four strands of the same wire which

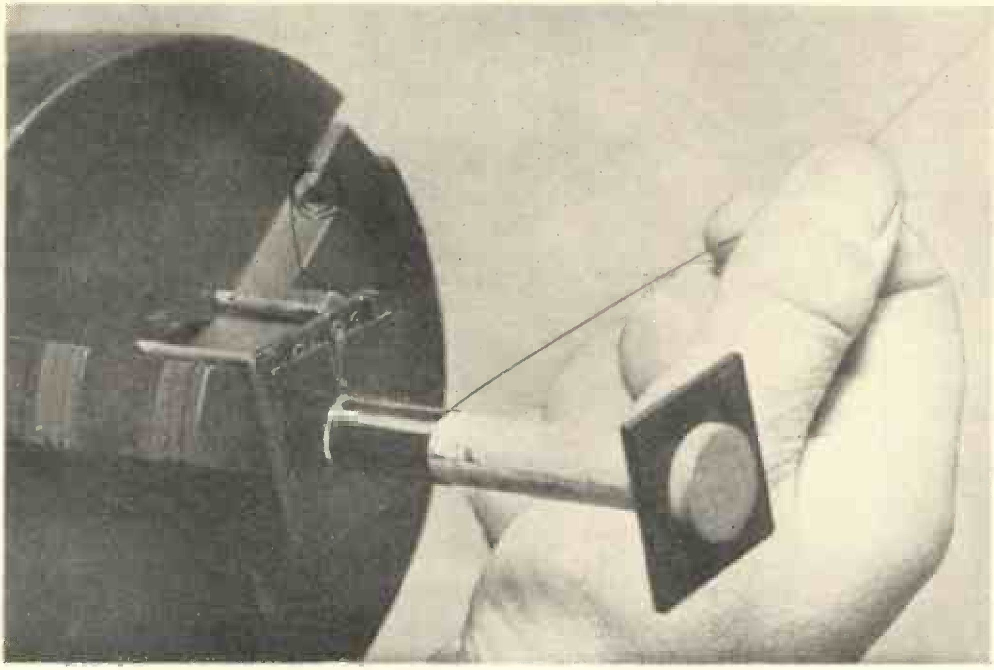


Fig. 14.—MAKING YOUR OWN RELAY—SECOND STAGE.
Winding the first layer of wire.

are covered with cotton braiding. This short flexible lead is soldered to the start of the wire and the joint covered with a small piece of empire tape. The winding is finished off in the same way. Fig. 14 shows the provision made for protecting the winding from the connections. The cheek of the bobbin is channelled out on the connecting tag side and a thin bakelite spacer is placed over it. This has a slot to enable the start of the winding to pass through to the hollow connecting tag, as shown in Fig. 14. When two or three layers have been wound, the bakelite spacer is squared up to register with the bobbin cheek.

Inter-layer Insulation

When the bobbin is wound with silk-covered wire, no inter-layer insulation need be used if care is taken to maintain the winding even. Enamel-covered wire requires thin paper insulation about every five layers for heavier gauges, such as 36 S.W.G., and every other layer for 40 S.W.G. Coils wound with wire finer than 40 S.W.G. should have paper between each layer.

The object of using paper in winding fine wire coils is not only to insulate adjacent layers, but to prevent the end turns from slipping down the ends of the winding and making contact with turns at a considerably different potential. The use of paper also keeps the main part of the winding even and allows the wire to expand and contract freely with changes in temperature due to the passage of a current through the coil.

The paper is cut about $\frac{3}{32}$ inch longer than the winding space and the edges serrated each end so that the paper takes up the form shown in Fig. 15.

Finishing the Coil

When the correct amount of wire has been put on, the end of the winding is tied with silk thread to prevent the winding becoming loose. The coil is then wrapped with a layer of empire cloth, as shown in Fig. 16. The coil is finally covered with linen-faced black paper, which should be stuck with an insulating varnish, and not water paste. The coil is now removed from the winding chuck, the ends cleaned and soldered to their tags or terminals.

RELAY CIRCUITS

All-Battery Set

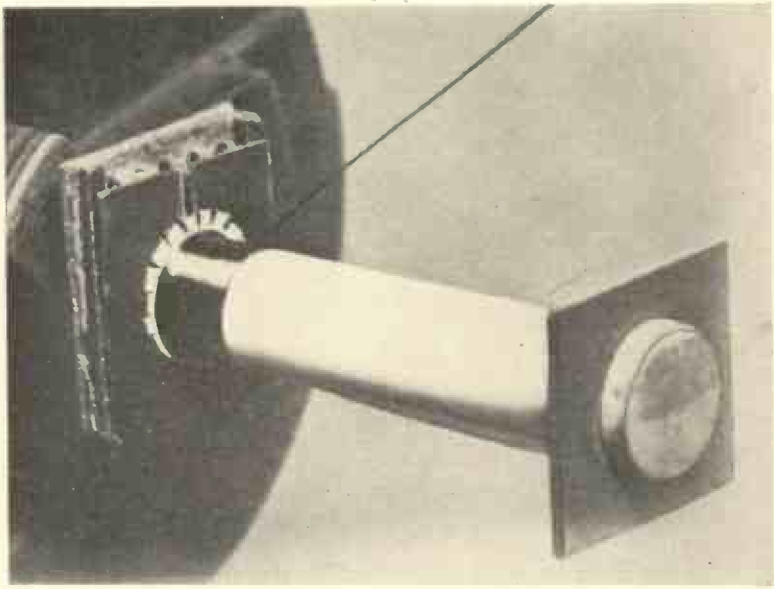


Fig. 15.—MAKING YOUR OWN RELAY—THIRD STAGE.

You will see that paper insulation is used between the layers to separate the winding and is spread over at the ends to prevent the ends becoming untidy. The paper should not be stuck.

Fig. 18 shows the connections for the remote switching of a wireless set, with batteries for both high and low tension. This circuit shows how the housing wiring may be done with three wires if a choke feed output is used for the loud speaker. One end of the relay coil is connected to low-tension battery positive, and the other end is connected to negative in series with a pair of contacts on the loud-speaker jack, which are closed when the plug is inserted. Thus the set is switched on by simply plugging the loud speaker into a remote jack. The contacts of the relay are connected in series with the positive supply of the low tension to the set. The high-tension battery is permanently connected to the set, as no current flows when the valves are cold.

House Wiring

As the wiring carries very little current, ordinary bell wire is amply heavy enough for the house wiring. If the wiring does not exceed 12 yards, triple bell wire may be used. When the total length of the house wiring exceeds this figure, it is better to run three single wires spaced apart so as to minimise the capacity across the loud speaker.

Control of H.T. Eliminator

Where the source of high tension is drawn from an eliminator while the low-tension supply is a battery, two pairs of contacts are necessary on the relay: one pair to switch the low tension, and the second pair to make and break the supply mains to the eliminator. The circuit for this type of set is shown in Fig. 19. This shows the use of remote switches to control the relay, but, as with the all-battery set, jacks may be used instead if desired. It will be seen that no part of the mains has any connection with the house wiring to the remote switches, so that, provided the insulation of the relay is good, there is no fear of shock from this part of the system.

Safeguarding Condensers

When an eliminator is used with a separate low-tension battery, it is always safer to switch the low tension on first and off last, so as not to strain the condensers in the eliminator. The use of a relay in this type of set prevents the high tension from being switched on first or switched off last because the contacts operate simultaneously. When both circuits are made simultaneously the valve filaments heat up before the eliminator condensers can be fully charged up, and when both circuits are broken together the eliminator condensers discharge before the valves have time to become cold. The need for safeguarding the condensers of an eliminator in this way is more important with A.C. than with D.C., because a 100-volt A.C. supply has a peak voltage of 141 volts.

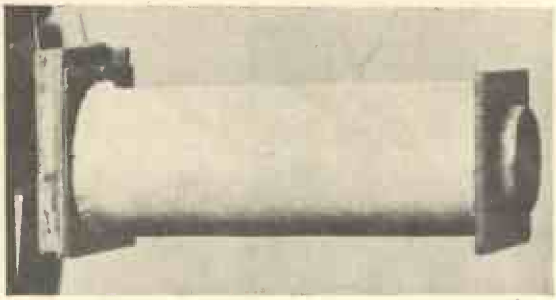


Fig. 16.—The Finished Winding Covered with Empire Cloth.

Control of D.C. All-Mains Sets

The circuit for the remote control of D.C. all-mains receiver is shown in Fig. 20. Although the mains could be used to operate the relay by having a coil wound to suit the supply voltage, it necessitates better house wiring than when a small local battery is used as shown. The double-pole double-throw switch provides a means of charging the accumulator without any trouble. When the switch is "up" the mains have no connection with the relay circuit. When the switch is "down" the battery is put in series with the supply to the set, so that it is charged while the set is in use. If the switch is connected in the earthed side of the main there is less danger of shock from the house wiring. Where it is found that the accumulator distracts from the efficiency of the receiver when on charge, owing to the small decrease in voltage applied to the set, the accumulator must be charged independently.

A.C. All-Mains Set

The three preceding types of wireless sets all give a ready method of obtaining a low voltage source of direct current supply for the operation of the relay. An A.C. mains set, to be self-contained, must dispense with the accumulator. The relay is therefore operated by alternating current, which is supplied by a small step-down transformer such as is used for working bells. The relay must be specially wound for an A.C. supply and the iron circuit must be laminated. The circuit is shown in Fig. 21.

Other Uses of Relays in Wireless

The foregoing uses of relays indicate their simplest applications to wireless receivers. Further refinements may be achieved by arranging relays to switch the tuning circuits from remote points, which, of course, means more house wiring. By arranging, say, 5 relays to short-circuit different portions of the tuning circuit it is possible to obtain a selection of five programmes. Another refinement may be added by arranging the relay to short-circuit the aerial and earth when the set is off. This is done by using a relay of the type shown in Fig. 11. One movable contact is connected to earth and the corresponding bottom contact is connected to the aerial. This, of course, adds to the capacity between the aerial and earth.

Remote Tuning

Remote tuning by means of relays has its limitations, because it necessitates multiplicity of relays, house wiring and switches. Up to a selection of five programmes remote tuning may be effected by having small pre-set condensers across the tuning inductances. Each condenser is set to give the required programme beforehand, so that, as each condenser is short-circuited by its respective re-

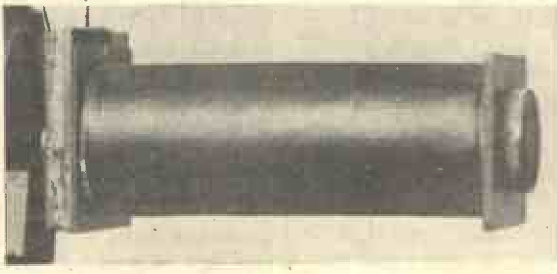
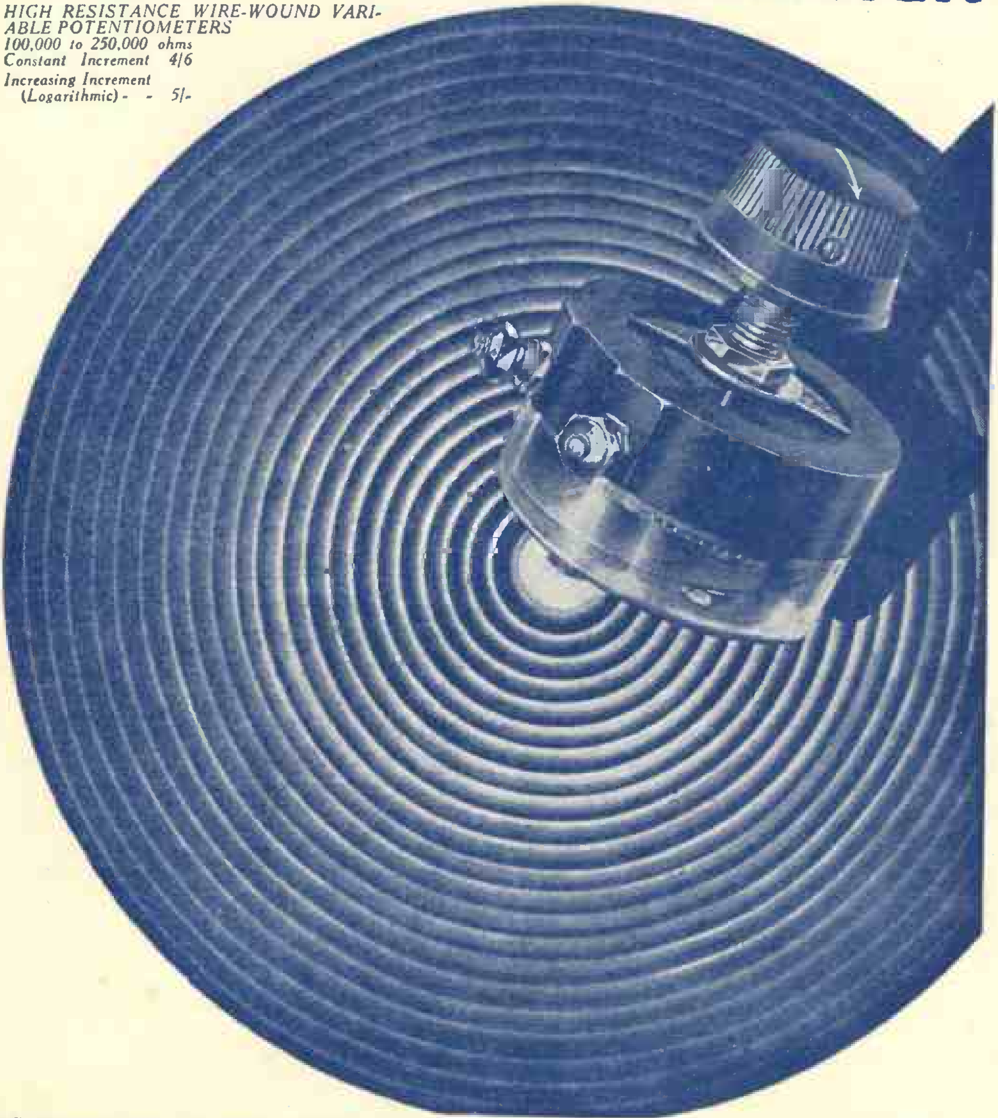


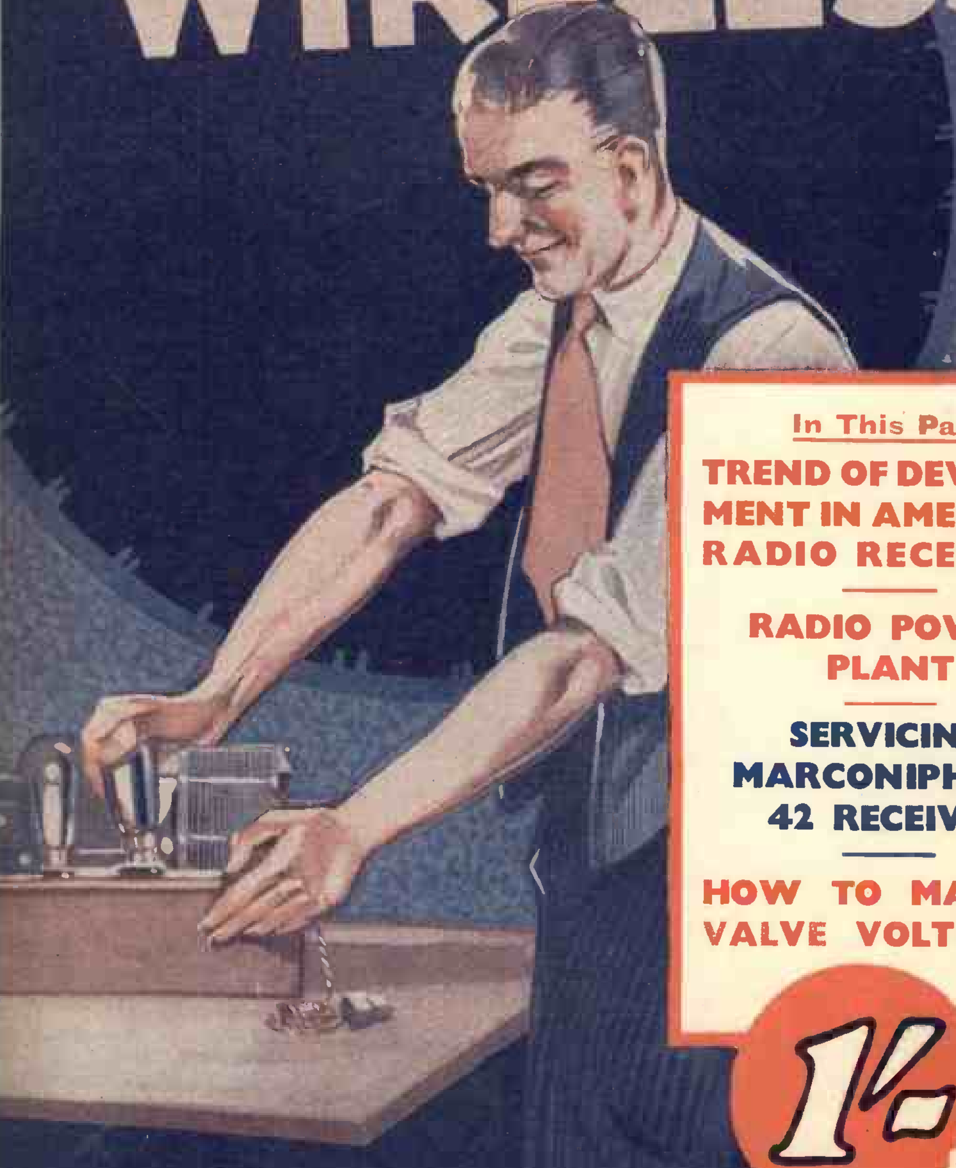
Fig. 17.—The Finished Coil Covered with Linen-faced Black Paper.



Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia : GORDON & GOTCH (Australasia) LTD. South Africa : CENTRAL NEWS AGENCY LTD.

CONSTRUCTION • EXPERIMENTAL • THEORY

NEWNES COMPLETE WIRELESS



In This Part

TREND OF DEVELOPMENT IN AMERICAN RADIO RECEPTION

RADIO POWER PLANT

SERVICING MARCONIPHONE 42 RECEIVER

HOW TO MAKE A VALVE VOLTMETER

1/-

Part 13

IN ABOUT 24 WEEKLY PARTS

Geo. Newnes Ltd.

lay from the remote control panel, the necessary change of tuning is effected. Where the set has only one tuning inductance the relays have only one set of contacts each. One relay is necessary for each setting in addition to the relay used to switch the set on and off. For multi-valve sets, where there is more than one tuning condenser, a set of contacts will be required on each relay for each of the main tuning condensers.

Where band-pass tuning is employed the input filters require two sets of contacts in addition to those necessary for the high-frequency amplifiers. As the relays for controlling the amount of capacity across the tuning inductances have, in the instance of a multi-valve set, two or more sets of contacts in close proximity controlling high-frequency circuits in different stages of amplification, each set of contacts must be effectively screened. The wires of each set of contacts must also be screened from one another. This may be done by using metal braided leads and earthing the casing. The overall amplification will be reduced somewhat by the extra capacity introduced into the high-frequency circuits.

Mercury Break Relays

A type of relay particularly adapted to remote tuning control systems has, instead of the usual spring blades, small mercury switches. These consist of sealed glass tubes containing a small quantity of mercury, which forms the circuit when the tube is tilted. The single-throw type of switch has the platinum contacts sealed in one end of a straight tube so that a tilt of about 6 degrees causes the mercury to run to the end of the tube in which the contacts are sealed. The change-over type is semi-circular in shape with three contacts so arranged that the centre one is alternately connected to the other two.

This type of switch has the advantage that it cannot become dirty and so give an unreliable contact. This is because the tube is not only sealed, but is filled with an inert gas which does not oxidise the mercury when a rupture arc takes place.

Remote Tuning by Motor

Continuously variable remote tuning can only be obtained by driving the condenser spindle with an electric motor. This method is practicable only when the tuning condensers are ganged; that is to say, when the tuning condensers are linked together on a common shaft.

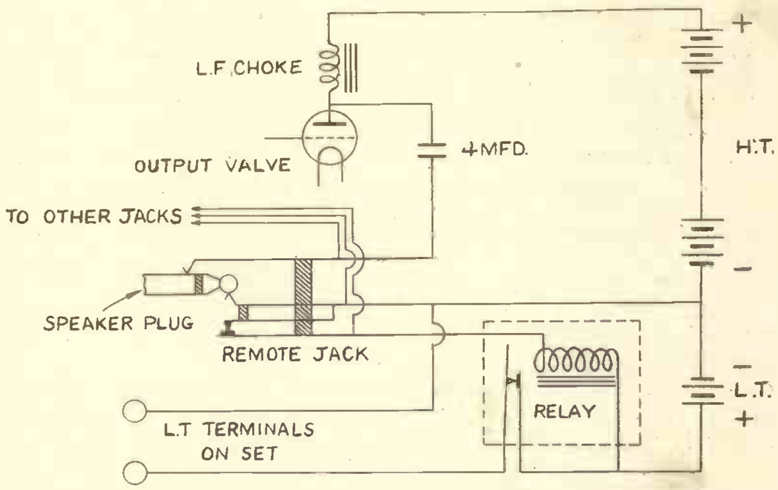


Fig. 18.—THE CIRCUIT FOR THE REMOTE CONTROL OF AN ALL-BATTERY SET.
Showing the use of a jack and plug to operate the relay. To switch on the set it is only necessary to insert the loud speaker plug into a remote jack.

The motor is geared to the spindle of the condensers by reduction gearing so as to give a slow-driving speed to the moving vanes. As modern types of condensers will not turn through a complete revolution the motor must be reversible. Where a series or shunt wound motor is used this is done by arranging the remote switch to reverse the motor field. The motor may be switched on and off by direct wiring or a relay may be used. The use of a relay is preferable because the wiring

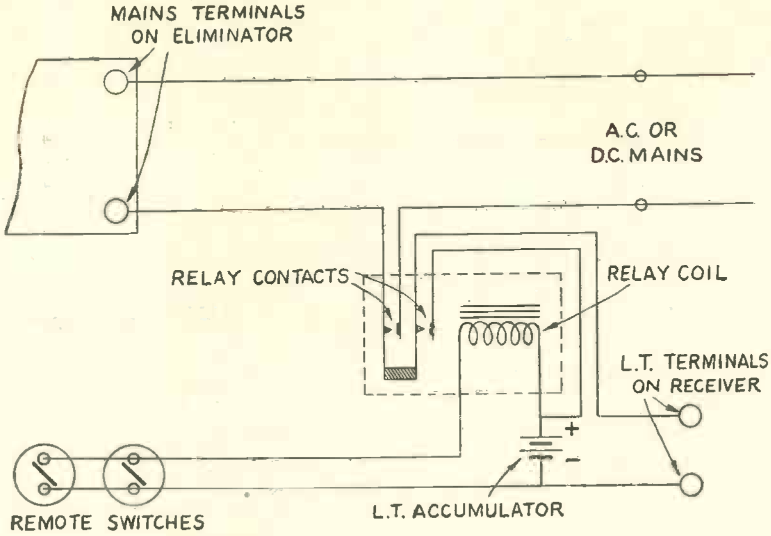


Fig. 19.—The Circuit for the Remote Control of a Wireless Receiver using a High Tension Eliminator and a Low Tension Accumulator.

A double-contact relay is necessary for this.

carrying the motor current may cause interference with the loud speaker extension leads.

A small type of self-starting induction motor has been produced for the remote operation of the tuning and volume controls. Screening and earthing of the motor is essential. If a commutator motor is used it will cause interference with the tuning circuits unless it is screened, more particularly when the motor is driven by alternating current.

The National Company of America have perfected a combined remote tuning and volume control system, using small motors of a special type which are controlled by two knobs on the remote panel. The motors are rotated by turning the knobs on the control panel in the desired direction.

Remote Volume Control

Remote volume control may be effected by the use of small electric motors in the same way as for tuning. A limited amount of volume control can be obtained by connecting a potentiometer across the output circuit to the loud speaker.

Obtaining Maximum Variation in Volume

In order to obtain the maximum variation in volume, the set is tuned to the loudest station and then adjusted to give the maximum permissible volume without distortion. There is then no fear of the output valve being overloaded at any setting of the remote tuning control.

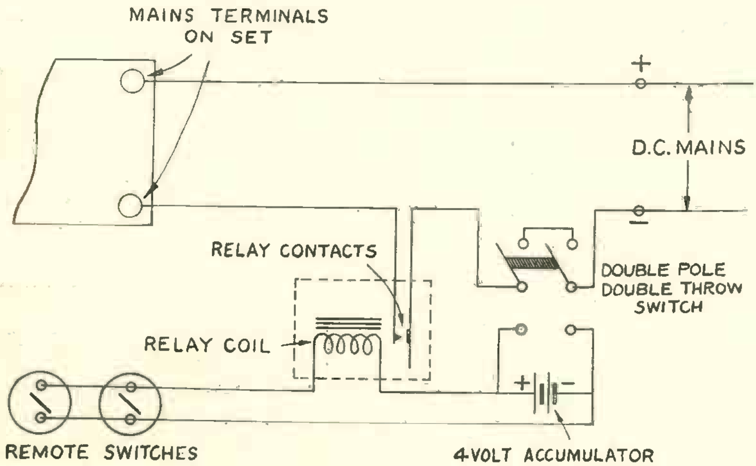


Fig. 20.—The Remote Control Circuit of a D.C. All-Mains Receiver.

A change-over switch provides a ready means of charging the accumulator without any extra apparatus.

Remote Control when using Variable-mu H.F. Stages

The control of volume by means of a potentiometer across the loud speaker is liable to lead to a good deal of distortion, because at the lower volume levels the loading of the output valve is considerably upset. When the receiver has one or more variable-mu high-frequency stages a very satisfactory method of remote volume control is available.

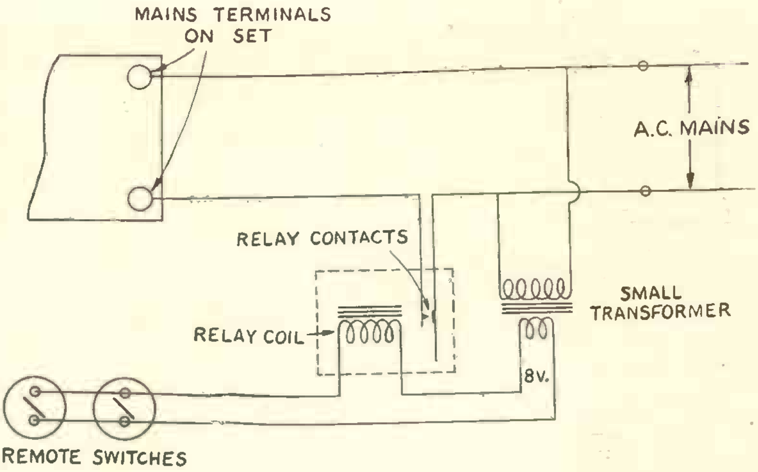


Fig. 21.—THE CIRCUIT ARRANGEMENT OF A.C. ALL-MAINS WIRELESS SET.
A relay designed to work on alternating current is used in conjunction with a small step-down transformer such as is used for house bells.

Variable-mu Mains Set

In a variable-mu A.C. mains set the control of volume is obtained by means of a single rheostat, which alters the grid-bias voltage of these valves. To obtain remote volume control with a set of this kind, it is necessary to remove the variable resistance from the receiver. The resistance is then mounted on the remote control panel with the other distant control apparatus, and the two leads in the set, belonging to the resistance, are extended to the panel. It is advisable to run these extension leads with screened wiring, especially as the set is an A.C. mains-driven type. Lead-covered bell-wire would be quite suitable for this.

Variable-mu Battery Set

A battery-operated variable-mu receiver has a potentiometer for controlling the volume and grid bias of the high-frequency valves. The remote control is obtained in the same way as for a mains set, except that three extension leads are necessary. Screening of the leads is not so important with a battery set, but should be used if A.C. mains are present in the house.

Indicator Lamps

When remote switching is installed, there is always a possibility of the set being left on all night, or at other periods when there is no transmission. This objection is overcome if an indicator lamp is placed in a prominent position, so that a visible indication that the set is on or off is automatically obtained. The current for the lamp may be conveniently obtained from the same source as that used for operating the relay, so that the lamp is lit whenever the relay is energised. This means that the lamp will be in parallel with the relay windings. When the relay is operated from a separate source of low-tension supply, the lamp may be connected in parallel with the filaments or heaters of the valves, in the same way as the dial light is usually wired. When the indicator lamp is lit with A.C., take care not to run the A.C. leads parallel to the loud speaker extension wiring. It will generally be advisable to run these A.C. leads in earthed lead-covered wire to avoid any possibility of interference in this direction.

To avoid premature failure of the indicator lamps, use bulbs of somewhat higher voltage than the supply. Thus a 6-volt lamp would be satisfactory on a 4-volt supply, and an 8-volt lamp would give long service on 6 volts. Although the bulbs are under-run when used in this way, they light quite brilliantly enough for the purpose of indicators.

HOW TO MAKE A VALVE VOLTMETER

By H. E. J. BUTLER

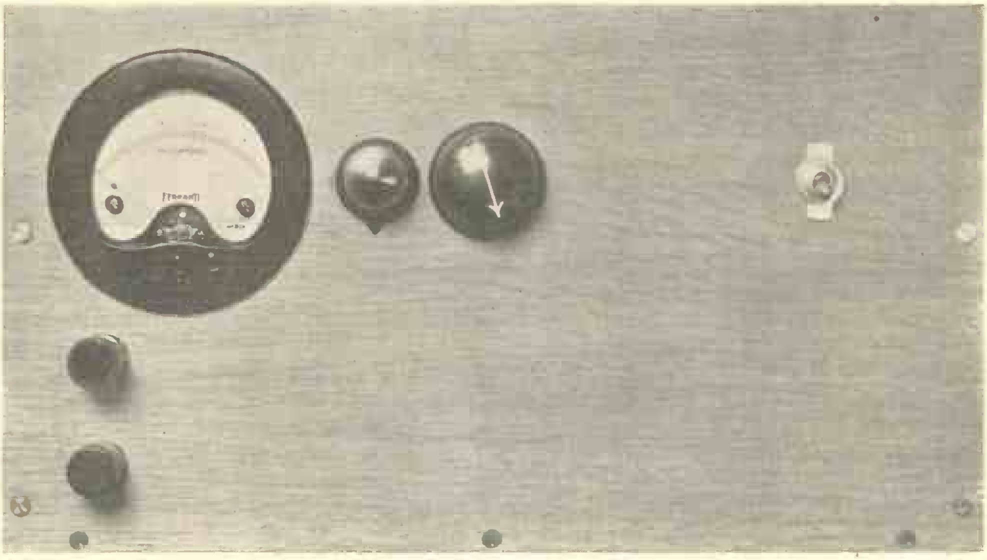


Fig. 1.—The Panel of the Mains-Driven Valve Voltmeter.

THE measurement of high-frequency voltages and currents presents a special problem. High-frequency currents can be measured by means of a thermo-ammeter or milliammeter, which is a direct reading instrument giving readings of equal accuracy either on D.C. or A.C. of any frequency.

High-frequency voltages below about 10 volts cannot be measured by any kind of direct reading instrument yet devised, because such an instrument, however sensitive, would impose a considerable load on the high-frequency circuit. This would give an inaccurate result.

It is the inherent property of a thermionic valve that a change in voltage applied to its grid, results in a change in the current flowing in its anode circuit. Moreover, the damping or loading effect on the circuit, supplying the voltage across the grid and cathode of the valve, is negligible.

How the Valve Voltmeter detects Small Voltages of Radio and Lower Frequencies

The valve voltmeter utilises this property of the valve to detect small voltages of radio and lower frequencies. The indicating component of a valve voltmeter is a low reading milliammeter which is placed in the anode circuit of the valve. In order to be able to read the changes in anode current in terms of volts, it is necessary only to apply various known A.C. voltages, of any frequency, to the grid, and plot the changes which take place as shown by the milliammeter. To make the milliammeter as sensitive as possible it is necessary to balance out the steady current of the valve so that the instrument reads only changes in current, not the total resultant current. A negative bias of $4\frac{1}{2}$ volts is applied to the grid of the valve by means of a small battery, so that the valve operates as an anode bend detector, or rectifier.

Components Required

1 mains transformer, type W.25 . . . . *Heayberd.*
1 metal rectifier, style H.T.6 (or H.T.7) . . . *Westinghouse.*
2 fixed non-inductive condensers, ·01 mfd. 250-volt A.C. working . *T.C.C.*

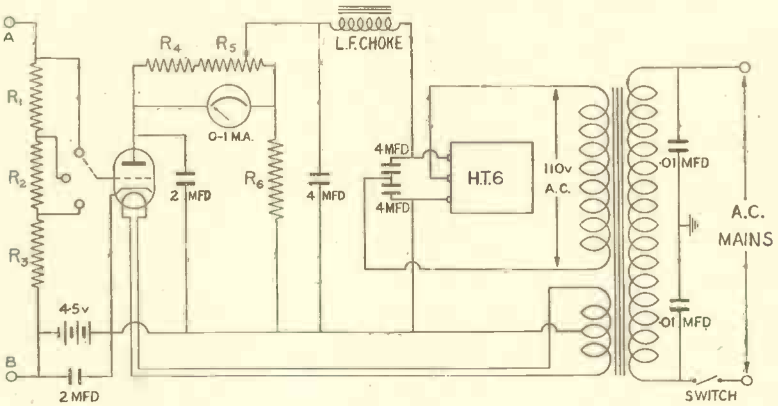


Fig. 2.—The Wiring Diagram of the Valve Voltmeter.
An H.T.7 metal rectifier can be used instead of the H.T.6, provided that the A.C. input voltage is 110 volts.

2 fixed condensers, 4 mfd. 250-volt D.C. working . *T.C.C.*
1 fixed condenser, 4 mfd. 250-volt A.C. working . *T.C.C.*
1 fixed non-inductive condenser, 2 mfd. 250-volt A.C. working . . *T.C.C.*
1 fixed non-inductive condenser, 2 mfd. 200-volts D.C. working . . *T.C.C.*
1 smoothing choke, type S20/25 . . . *Tunewell.*
1 fixed resistance, 20,000 ohms, 5-watt strip type *Colvern.*
1 fixed resistance, 4,000 ohms, 5-watt strip type *Colvern.*
1 potentiometer, 1,000 ohms, 10-watt type . *Colvern.*
1 fixed resistance, 50,000 ohms, 1-watt carbon type . . *Erie.*
1 fixed resistance, 40,000 ohms, 1-watt carbon type . . *Erie.*
1 fixed resistance, 10,000 ohms, 1-watt carbon type . . *Erie.*
1 three-way switch . . *Kabi.*
1 $4\frac{1}{2}$-volt grid battery . . *Exide.*
1 Mazda valve, A.C.2/ H.L. . *Mazda.*
1 milliammeter 0–1 m.a. $2\frac{1}{2}$-inch type . . . *Ferranti.*
1 Q.M.B. on-off switch . . *Bulgin.*
2 Belling-Lee terminals "Input" . . . *Belling-Lee.*
2 brackets, and coil of Glazite.

The Circuit

Fig. 2 shows the circuit of the mains-driven valve voltmeter. The circuit comprises the usual voltage doubler rectifier supplying about 200 volts to the anode of the valve. The usual valve voltmeter requires an extremely sensitive, and consequently expensive, microammeter. By using a steep-slope mains valve, such as the Mazda A.C.2/ H.L., it is possible to use a less sensitive instrument to indicate the changes in anode current. Since the set is mains operated it is not suitable for extremely accurate measurements, because fluctuations in the mains voltage will cause variations in the readings. When accuracy is essential the mains apparatus can be replaced by a 200-volt H.T. battery and a 4-volt accumulator.

Neutralising Anode Current

The steady anode current, which exists when there is no input voltage across A–B, is neutralised by means of an arrangement of resistances—R4, R5 and R6. The principle of this is best understood from Fig. 4. This shows that the three resistances, with the valve impedance Rv, constitute a Wheatstone bridge circuit. By choosing the values of the resistances so that the right-hand side of R5 is very small when a balance is obtained, the meter reads a large percentage of the change in current, due to the voltage input to the valve voltmeter. The balance of the circuit is upset when an A.C. voltage is applied to the grid, because it alters the effective impedance of the valve Rv, Fig. 4.

The Range of the Voltmeter

Without any means of extending the voltage range of the set, readings up to 1·5 volts can be obtained. The range is increased by using a potential divider consisting of three non-inductive resistances, R1, R2, R3. These resistances are arranged to give twice and ten times the range; which means readings up to 3 volts for the middle range, and up to 15 volts with the grid and cathode across R3. The total resistance of the potential divider is 100,000 ohms, so that to obtain twice the range R1 is equal to the sum of R2 plus R3, and to get ten times the range R3 is one-tenth of the total. This method of increasing the range will cause some power to be absorbed from the circuit. The inaccuracy so caused will be very slight in most tests. The range may be considerably increased by using a meter reading 0–5 milliamperes instead of 0–1 milliamperes. This will, of course, render the set less sensitive to very small inputs.

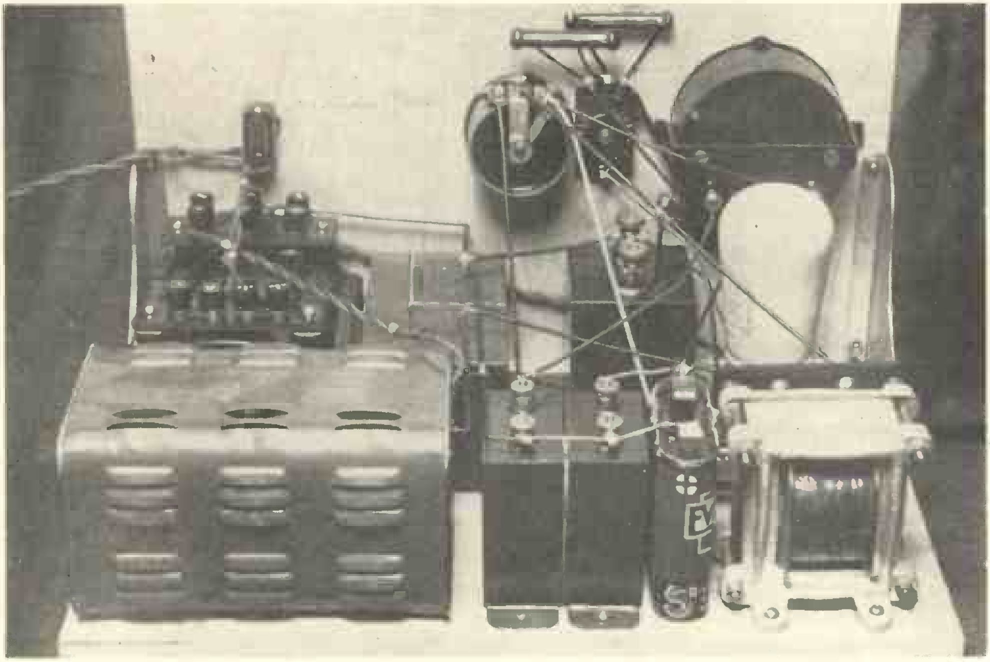


Fig. 3.—A View of the Completed Chassis of the Valve Voltmeter.
Showing the layout of the components and the wiring.

Single Range

The average experimenter may not require the ranges above 1·5 volts, in which instance the three Erie resistances and the three-way switch can be omitted. If this is done it is necessary to provide a D.C. conducting path between the input terminals of the valve voltmeter in order that the negative bias may be applied to the grid of the valve. Most tests are generally made across a coil of some kind, so that the necessary D.C. path is automatically obtained. When the testing circuit does not provide a D.C. path across the input terminals it is necessary to bridge them with a 1 megohm leak.

Constructing the Valve Voltmeter

The construction of the set is similar to the making of a mains-driven receiver. The first step is to fix the brackets to the baseboard and then screw the panel to the brackets. The panel is then removed so that the holes for the switch, potentiometer, three-way switch, terminals and milliammeter can be drilled. Before refixing the panel, the components are set out and screwed to the baseboard as shown in Figs. 3 and 5. The components are fixed to the panel. which is then screwed to the baseboard. If the panel is made of wood or metal it is necessary to place insulating bushes under the fixing nuts of the two Belling-Lee input terminals. It is not necessary to insulate the spindle of the three-way switch, because it does not form a part of the electrical circuit of the switch.

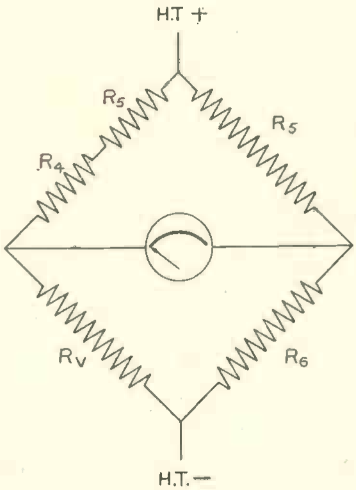


Fig. 4.—The Method of Neutralising the Steady Anode Current of the Valve is an Application of the Wheatstone Bridge circuit.

Wiring the Valve Voltmeter

Most of the wiring is carried out with coloured Glazite. All leads carrying A.C. should be screened by using twin screened sleeving. The completely wired set is shown in Figs. 3 and 5. Although a 4½-volt flash lamp battery is shown permanently wired in the set, it may be preferred to use a standard bias battery with wander plugs, so that the bias may be adjusted, and the battery more easily replaced when it is worn out.

The Non-inductive Resistances

The two Erie non-inductive resistances R1 and R2 are connected to the three-way switch by means of their own wire ends. The Erie resistance R3 is connected between the right-hand switch contact, as viewed from the back of the panel, and the upper input terminal. The wire ends of this resistance require an extension on one end to make it reach between these two points. This resistance is seen in Fig. 3 to the left, below the milliammeter. It is essential that the insulation of the 2 mfd. condenser, connected between the anode of the valve and negative H.T., should be beyond doubt.

Testing the Wiring

When the set has been wired, this is easily tested. Switch on the set with the valve removed, then, with the potentiometer set to read the steady anode current as shown in Fig. 3, the milliammeter should read zero if the insulation of this condenser and valve holder is in order. If the meter deflects slightly, disconnect the condenser and test again. Should the meter now indicate nothing the condenser is leaky. A reading of ·02 milliampere would indicate an insulation resistance of 12·5 megohms, which is not acceptable.

Do not use a Self-bias Resistance

Do not attempt to substitute a self-bias resistance for the dry battery, or the valve voltmeter will not work properly. This is because the increase in anode current due to a signal current results in an increase in bias which prevents the valve anode current from increasing as much as it would with a fixed battery bias. This makes the set insensitive. The bias battery could be substituted by a separate grid bias eliminator, but this would add very much to the cost and would not be justified.

Starting the Set

When the set has been wired, and the connections carefully checked, the transformer primary is connected to the mains, *viâ* the Q.M.B. switch. Before switching on, make sure that the potentiometer is turned to read fully the steady anode current. The position of the potentiometer arm is shown in this position in Fig. 3. As the set is switched on, the meter will momentarily read full-scale, while the valve condenser charges up. The meter will then gradually increase from zero as the valve warms up. As the current increases the potentiometer is then turned slowly until the milliammeter again reads zero. The set is left on for at least ten minutes before use, to make sure that the valve is thoroughly warmed up and will not necessitate any further adjustment of the potentiometer.

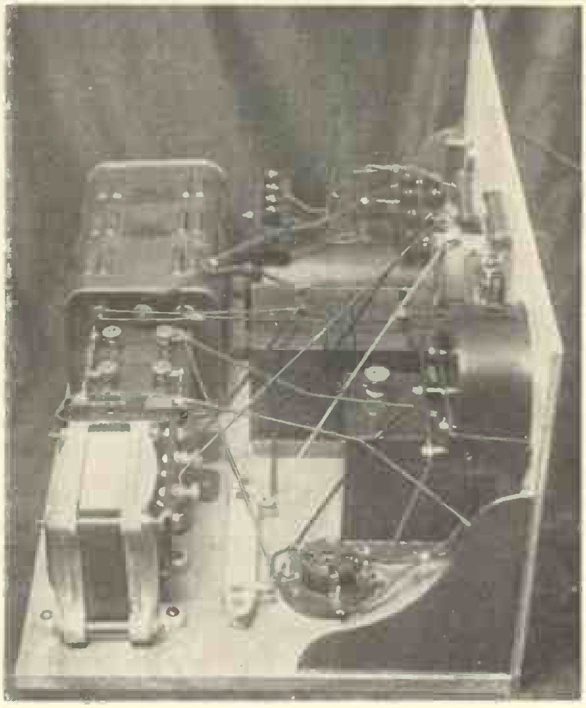


Fig. 5.—AN END VIEW OF THE SET.
Showing more of the wiring. The two Colvern strip resistances are mounted one above the other.

USES OF THE VALVE VOLTMETER

A valve voltmeter has a large number of uses, even if it is not calibrated. For comparing the efficiency and for the matching of tuning inductances the valve voltmeter need not be calibrated, because only comparative results are required. These two tests are probably those which will be most useful.

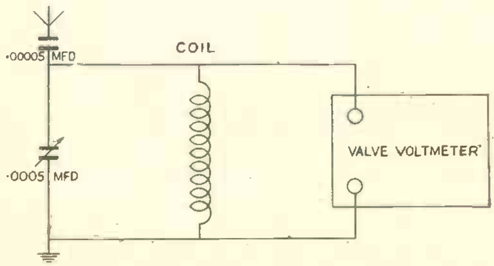


Fig. 6.—A SIMPLE CIRCUIT FOR COMPARING AND MATCHING TUNING COILS.

Testing Relative Efficiency of Tuning Coils

The circuit for testing the relative efficiency of tuning coils is shown in Fig. 6. The coil is tuned to a local station by means of a variable condenser. The tuning condenser is adjusted until the valve voltmeter reads a maximum. The other coils are then substituted and the different maximum readings noted. The coil which gives the highest maximum reading on the valve voltmeter is the most efficient one. It is essential when conducting the test to ensure that the same transmission is tuned for each coil. If the coils are much different, there may be some doubt as to whether the same station is tuned each time, when there are two transmissions of about equal strength.

Using a Valve Oscillator

This difficulty is overcome if a valve oscillator is used instead of a broadcast transmission. A wireless receiver can be used instead of a separate oscillator if it is a type which re-radiates when the reaction is increased. It is necessary to disconnect the aerial and substitute a

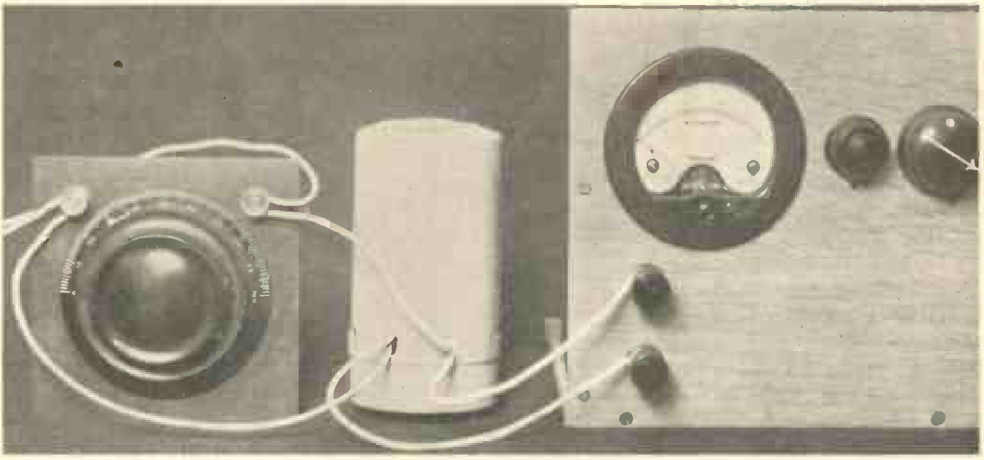


Fig. 7.—USING THE VALVE VOLTMETER FOR MATCHING SCREENED COILS.
A slow motion condenser drive is essential for a test of this kind.

short wire loop when using a receiver as a test oscillator, or interference to neighbouring receivers will result.

Matching Coils

The valve voltmeter is very useful for matching tuning coils, which are to be used in ganged circuits. A simple method of doing this is illustrated in Fig. 6. The first of the coils to be matched is connected in the manner shown in Fig. 7. A local station is then tuned in by means of the variable condenser. The condenser setting which gives the maximum reading on the milliammeter of the valve voltmeter is noted. Suppose it is 35 degrees. The coil is now disconnected and a second coil substituted, using the same leads placed in an identical manner to that of the first tests. The condenser setting for the maximum voltage from the same transmission is then noted for the second coil. Suppose this reading is 34 degrees, the inductance of the second coil is larger than that of the first.

How to Lower the Inductance

The inductance is lowered by spacing out the end turns slightly, or by removing half or one turn to bring the two into line. It is not sufficient to match the coils by comparing the amount of capacity required to turn them to only one particular wavelength. A second transmission should then be chosen and the test repeated before any adjustment in the turns is made. If it is found that the second coil still requires a lower condenser setting, by a similar small amount, it is certain that only the inductance and not the self-capacity is different.

Matching Coils of Dissimilar Proportions

A tuning coil possesses three properties, namely, inductance, capacity and resistance. The D.C. resistance does not enter into the present consideration, so that only inductance and capacity have to be taken into account when matching coils. If two coils are of the same dimensions, and the wire and number of turns are the same also, their capacity may be assumed to be the same. Suppose, however, two or more coils, wound on different sizes of formers, have to be matched; their capacities will almost inevitably be different. The capacities do not have to be matched, but they must be balanced before their inductances can be matched accurately.

Type of Condenser to use

It is preferable to use a straight-line-frequency tuning condenser when matching coils known to have different capacities. As an example of matching two coils having different dimensions, suppose readings of 35 degrees and 34 degrees are obtained on one transmission, and 7 degrees and 8 degrees respectively, for a second transmission.

How to Alter the Capacity

It is noticed from these results that the second coil requires less capacity than the first for the higher wavelength, but more than the first for the lower wavelength. This means that the first coil has a lower capacity than the second coil, although its inductance is greater. In order to make the capacity of the first coil equal to that of the second, a very small variable condenser is shunted across the former, and adjusted until the condenser readings differ by about the same amount on both wavelengths.

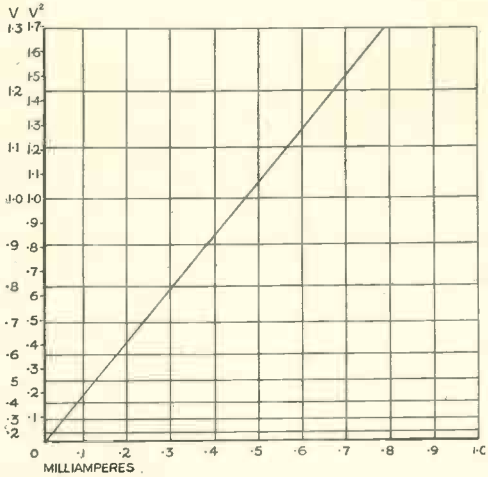


Fig. 8.—The Scale V is the Actual Voltage Readings Corresponding to the Milliammeter Readings.

The input voltages with the range switch in the middle position will be double for the same milliammeter readings and ten times for the highest range position of the switch.

It now remains to adjust the number of turns until the two coils give the same condenser readings for both transmissions. It is not necessary to take the self-capacity of a coil into account when watching inductance, unless there is a considerable difference in diameter of the coils.

What is Required for Ganging

The essential condition for ganging is that the several coils shall be of the same inductance and that the various condenser sections shall be matched at all settings. The stray capacities are brought into line by the trimmers of the gang condenser. (See also the article on "Ganged Coil Circuits" on p. 291.)

Calibrating the Valve Voltmeter

Since the readings of a valve voltmeter are independent of frequency, it is possible to calibrate the instrument with a commercial A.C. supply. The increase in anode current is not directly proportional to the voltage applied across the grid and cathode, but is proportional to the square of the applied volts.

How to work out a Curve for applied volts/milliammeter readings

It is therefore necessary to take several readings of the milliammeter so that a curve may be produced to give the relation between the applied volts and the milliammeter readings. The range switch of the valve voltmeter is set to the lowest scale, that is, with the grid and cathode across the whole of the 100,000 ohms potential divider. The set is then started up and anode current balanced out as previously described.

Plotting the Curve

For the purpose of calibration, stretch out a metre of bare 32 S.W.G. resistance wire and apply an A.C. voltage of 2 across the ends. A metre rule is then laid alongside the wire or potentiometer. Any two points 10 centimetres apart will give ·2 volts, and any two points 5 centimetres apart will give ·1 volt; and so on in proportion to the length of the wire across which the connection is made. An A.C. voltmeter is connected across the end connections of the wire to verify the voltage across the potentiometer. The cathode or upper input terminal of the valve voltmeter is connected to one end of the slide wire while the other is connected, in turn, to about six different points along the wire and the readings noted in relation to the voltage input.

Fig. 8 shows the results obtained. The vertical scale is the square of the input voltage, and the horizontal scale represents the change in anode current.

RADIO POWER PLANT

NOTES ON THE USES, INSTALLATION AND SERVICING OF ROTARY TRANSFORMERS, ROTARY CONVERTERS, MOTOR GENERATORS, AND HAND-DRIVEN GENERATORS, ETC.

By R. HARCOURT WOODALL, A.M.I.E.E.

SMALL rotary transformers are extensively used for supplying H.T. current to radio receiving sets and low-frequency amplifiers, particularly in districts where electricity supply mains do not exist, and in places where a low voltage lighting plant is installed. Also at the present time miniature rotary converters are used a great deal in D.C. districts for the operation of standard A.C. mains-operated receivers or radiograms.

Fig. 1.—An M-L Anode Converter with Lid removed (*Rotax Ltd.*).

In this article it is proposed first of all to deal with the application of these small electrical machines for radio and kindred purposes and afterwards with the installation and servicing of such machines. Finally the design of radio power plant and its attendant smoothing apparatus will be considered.

What the Rotary Transformer is Used for

The rotary transformer provides a means of "stepping up" or "stepping down" the voltage of a D.C. supply. Alternating currents can be transformed from one voltage to another by means of an ordinary static transformer with which the reader will, no doubt, be familiar already.

Apart from the use of an induction coil and rectifying unit it is not possible to transform the voltage of a D.C. supply other than by employing a rotating machine, and the rotary transformer is the machine most widely used for this purpose. Without going into the design at this stage it is sufficient to say that such a machine consists of an armature having two windings and two commutators, which revolves in a magnetic field.

How it Works

Current is fed into one winding, usually called the primary winding, by means of two brushes which make contact with the commutator connected to that winding. The armature rotates, the principle being

Fig. 2.—An M-L Anode Converter connected to a Modern Short-wave Receiver (*Rotax Ltd.*).

that of the D.C. motor, which is stated thus : if a conductor carrying a current is placed in a magnetic field in the same plane as the field, but at right angles to it, it will be acted upon by a force tending to move it so as to cut the lines of the magnetic field.

The armature thus revolving has an electromotive force or voltage induced in its secondary winding which produces a current in an external circuit connected to it by means of the brushes which make contact with the secondary commutator. This is explained by considering the principle of the D.C. dynamo, which states :—if a conductor is moved in a magnetic field so as to cut the field, an E.M.F. will be induced in it. In the case of the rotary transformer mentioned, the external circuit will, of course, consist of the anode circuit of the receiver.

The rotary transformer therefore combines a motor and generator, the magnetic field being common to both.

For the benefit of the reader not familiar with the action of the commutators it should be stated that these act as rectifiers, the actual currents flowing in the armature being alternating.

How it is used for Radio Reception

The rotary transformer is, of course, adaptable by suitably winding the armature to operate from any voltage and to give its output at any desired voltage. For instance, correctly wound, a rotary transformer can take current from 200 v. D.C. mains and give 400 volts D.C. across its output terminals. On the other hand, it may be wound to operate from the same supply and give a 6-volt D.C. output. It is, therefore, obvious that in the rotary transformer we have an exceedingly useful machine which renders D.C. circuits as flexible as A.C. mains.

Supplying Anode Current

Here then we have first of all a machine which will enable the user to obtain an anode supply for his receiver, even if his only available D.C. supply is a 6-volt accumulator. A rotary transformer will step-up 6 volts to 150 or 200 volts. Modern receivers demand heavy anode currents at fairly high voltages, and in many instances dry batteries will not be found to be reliable, since it is well known that their milliampere discharge is limited and that parasitic noises are always liable to be produced by them after they have been in service some time.

Worked from same Accumulator as that which heats Valve Filaments

We have mentioned heavy anode currents, and whilst it is admitted that quite a number of receivers are produced which only consume 7 to 10 milliamps, it is generally agreed that if quality is not to be sacrificed the consumption often amounts to 15 to 30 milliamps, and many commercial receivers can be instanced which actually fall within this category. Under these conditions, therefore, the only alternatives are the H.T. accumulator and the rotary transformer, and as we are dealing with the listener without mains, the latter is to be recommended, since charging facilities are not always available for the former, which also require frequent attention if a long life is desired. The rotary transformer can be operated from the same accumulator as that which heats valve filaments, so that charging facilities for one L.T. battery is all that is necessary.

Fig. 3.—AN M-L 100-WATT ROTARY TRANSFORMER (*Rotax Ltd.*).
With end cover partially removed.

Conditions in Tropical Regions

Mention must here be made of the problem confronting the broadcast listener situated in a tropical or semi-tropical region. In such places radio, in the absence of other forms of amusement, becomes a necessity rather than a luxury. Local conditions make short-wave reception essential, and invariably the lack of a local broadcasting station or the desire to listen to the Homeland on the part of the settlers means that the receiver must be powerful. The only solution to the anode supply problem is the rotary transformer, dry batteries being entirely out of the question owing to the fact that the atmospheric conditions in these regions may render them useless, sometimes before being put into service.

Houses with Private D.C. Lighting Plant

In all territory not served by electric supply mains there is always found a large number of houses in which private D.C. lighting plant is installed. This plant usually incorporates a battery of 32, 50 or 110 volts D.C., these voltages being, obviously, not high enough for anode supply. In such cases a rotary transformer may be used to step up to a suitable voltage for the provision of plate current.

A rotary transformer in commercial form is shown in Fig. 1. This is the M-L Anode Converter, which was the first machine of its type to be produced. The apparatus consists of a rotary transformer and smoothing circuit, the whole being mounted in a soundproof box. Fig. 2 shows the converter connected to a modern receiver. It should, of course, be pointed out that by the connection of suitable resistances in the output circuit the machine will provide grid bias as well as anode current.

The Transformer does not Cause Hum or Crackle

One may reasonably ask the question whether these machines will not themselves cause interference with reception, such as the noises that are sometimes heard when lift motors, fans, traffic signals, etc., are situated in close proximity to the receiver. The answer is that the present-day rotary transformer will operate even the most sensitive radio receiver without producing any hum or crackle in the loud speaker. Indeed the actual hum is invariably less than that produced in the loud speaker of many modern A.C. mains-operated receivers. Perhaps the most sensitive receivers in this respect are the superheterodyne and the short-wave receiver, and it will suffice to say that these are operated by machines without difficulty.

L.F. Amplification

When one is concerned with the anode supply for a large power amplifier employing valves of the L.S.5A. or L.S.6A. class, and when this amplifier is part of a public address equipment which may be frequently used in a country district remote from a mains supply, the use of a D.C. to

D.C. rotary transformer delivering 400 or 500 volts and taking current from a 12-volt accumulator is undoubtedly a proposition. Such equipment is invariably carried on a van, the starter battery of which can be used for driving purposes. A very compact machine of light weight compares very favourably with a heavy and bulky H.T. accumulator to provide the same output. A typical machine might deliver 250 milliamps at 400 volts D.C., taking 13½ amperes at 12 volts, this showing the remarkably high efficiency of 62 per cent. The weight would be 14 lbs. (Fig. 3).

In a D.C. district one might use a similar machine to the above, but wound for a 200 to 250 volt D.C. input.

Automobile Radio Equipment

Mention of the installation of a rotary transformer on a van brings us to the interesting fact that anode current for a majority of the receivers fitted as standard to so many automobiles in America is derived from a rotary transformer or "Magmotor," as it is called over there. Already in this country large numbers of police cars and vans, including the famous "Flying Squad," have a radio receiver fitted, these being operated by machines of the type mentioned.

Low-power Transmission

For low-power transmission purposes anode current at 750 to 1,500 volts D.C. is required, and here again one finds a wide field of application for rotary transformers. The amateur transmitter having D.C. mains in his station can use a machine to obtain a suitably high voltage for his transmitting valve plate. A similar model wound for a 12-volt input can be used for direction-finding competitions, etc., which take place in the open. Machines of the latter type are now being extensively used for radio transmission on aircraft, the input current being derived from a 12-volt engine-driven dynamo across which is connected an accumulator. The air-driven generators used for this purpose in the past are gradually to be replaced by rotary transformers owing to the effect which the small windmills have on the speed of the craft. In the case of many rotary transformers for transmitting purposes a "chopper wheel," or interrupter disc, is fitted to the spindle, the function of this being to interrupt the circuit at a certain frequency when one is desirous of transmitting I.C.W. (interrupted continuous wave).

Mention should also be made of the use of rotary transformers on ships, yachts and lighthouses, all of which are provided with a D.C. supply.

Rotary Converters and D.C. to A.C. Rotary Transformers

Now let us consider the applications of machines which will convert D.C. of any voltage into A.C. Large machines which perform this function in a power station are termed "Rotary Converters," the armature having only one winding, a commutator and a pair of slip-rings. The latter are connected across two opposite points on the D.C. winding, so that there is an electrical connection between the D.C. and A.C. circuits, the output voltage being the input voltage divided by $\sqrt{2}$. For reasons which will be dealt with later, this type of machine is unsuitable for radio work, and so use is made of the D.C. to A.C. rotary transformer, which, like the D.C. to D.C. machine, has two windings. One is connected to a commutator and the other to a pair of slip-rings.

How Listeners with D.C. Mains can use A.C. Sets

This type of machine, giving, as it does, an A.C. output of 230 volts, 50 cycles, is suitable for the operation of any A.C. mains-driven receivers or radiograms. Thus may listeners with D.C. mains enjoy results not possible with D.C. mains receivers. D.C. mains in various parts of the country cannot be said to be uniform. Some consist of rectified alternating current produced by means of mercury vapour rectifiers. Such mains are very rough and cause hum if a D.C. receiver is employed. Similarly, this machine has its uses in the country house having private D.C. plant, the voltage of 32, 50 or 110 volts D.C. being converted to 230 volts, 50 cycles.

Motor Generator Sets for Delivering both L.T. and H.T. Output

Having dealt with rotary transformers capable of either a H.T., a L.T., or an A.C. output, we will now consider the use of a machine capable of delivering both a L.T. and a H.T. output.

This is possible if a machine such as those previously described is fitted with an extended spindle and driven by an external motor.

By the use of suitable motors, motor generator sets can be produced to run from A.C. or D.C. mains.

In such sets the generators are usually driven at a speed of 1,450 r.p.m. or 2,900 r.p.m. For A.C. operation, induction motors are often used for driving purposes. For D.C. supplies, shunt or compound wound motors are used.

Often the motors and generators are built into a common shell, the armatures being on the same shaft, but having separate fields. One typical motor generator designed for marine use is wound to run from a D.C. supply and provides a H.T. direct-current output for radio transmitting purposes. A third winding on the same shaft gives a low-tension supply for valve filaments.

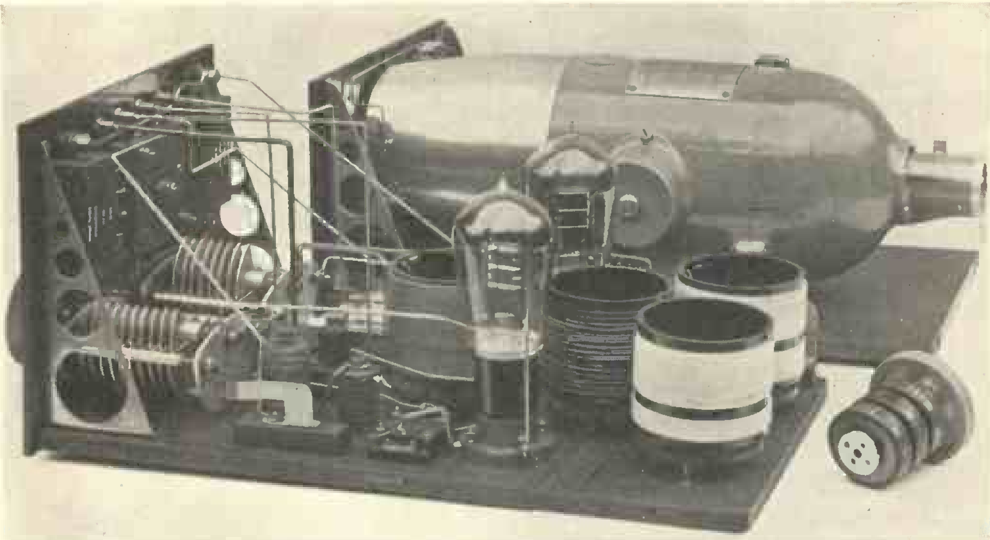


Fig. 4.—A Hand-driven Generator with Automatic Signalling (*Mortley, Sprague & Co. Ltd.*). Showing emergency transmitter and signal discs.

A generator with two windings is direct coupled to the motor by a flexible coupling. When driven at the correct speed, the generator will furnish two outputs, and is usually arranged for one of these to give L.T. for valve filament and the other to give H.T. current for valve anodes.

Where D.C. mains only are available such a set provides the only economical method of obtaining anode and filament current for high-power receivers or for transmitting sets.

Even when A.C. is available, motor generator sets compare very favourably with rectifiers when L.T. and H.T. are required to the extent of 100 or 200 watts.

Hand-driven Generators

The use of a hand-driven generator for emergency radio transmitting purposes has been a boon to many radio operators on aircraft engaged on long and hazardous journeys. In the case of aircraft carrying air-driven generators to provide normal anode and filament supply for transmitters, it is essential to have on board some form of apparatus which will function when, a forced landing having been made, the above-mentioned generator is out of action. The hand-operated generator is ideal for this purpose, and by its use sufficient L.T. and H.T. current can be generated to operate an emergency transmitter. This type of machine consists essentially of a double-wound dynamo arranged with gearing and driving handle so that the full output of the machine can be obtained by turning the handle at about 90 to 100 r.p.m.

Naturally the output derived from such a machine is limited and it is not possible to operate a hand-driven generator to give more than about 40 watts, unless more than one handle is fitted, and for emergency purposes this is not a proposition. The general construction of the generator is similar to the rotary transformer described later. The gearing ratio is usually about 25 to 1.

Fig. 5.—Starting an Anode Converter.
Note that the rheostat also controls the output volts.

Frost's Automatic Signalling Device

By the incorporation of a clever device designed and patented by Captain S. G. Frost (late of the R.A.F.), it is now possible for an operator without knowledge of Morse to transmit a message by merely turning the handle of the generator. The device consists of a spindle driven by an intermediate shaft in the generator gear-box. This spindle carries a number of "Stabilite" discs having brass inserts in the form of dots and dashes on their periphery. These discs are usually made up of sectors, each of which is made to represent a letter in the Morse alphabet. It will thus be seen that by suitably arranging these sectors a definite coded signal, such as "S.O.S.," can be formed. Contact to the discs is made by two plungers, these being connected to a terminal box on top of the machine. This interrupter is connected in the transmitting circuit in place of the key, and by the turning of the handle of the generator the signal will be repeated.

The signal discs are clearly shown on the right-hand side of Fig. 4, which shows a Mortley, Sprague Emergency Hand-driven Generator with Frost attachment connected to a transmitter. Incidentally, this particular model is a dual purpose machine, since it can be adapted for airscrew drive by removing driving handle and fitting a flexible shaft which engages with the armature spindle, the gearing being inoperative.

There are many uses for hand-driven generators, apart from their use on aircraft, and this type of machine undoubtedly has a big future. The settler in a remote district could make use of it for summoning medical aid, police, fire brigade, etc. Small sea-going vessels could send out emergency signals without a skilled operator on board and without the necessity of maintaining an elaborate power plant.

Special Machines

In addition to the rotary transformers

motor generators, and hand-driven generators already dealt with in this article, there are many special-purpose machines designed and manufactured for radio purposes.

For marine transmitting sets a H.F. supply is often required, and this is obtained from a motor alternator designed to give a 500-cycle output.

For the operation of public address amplifiers on vans we have already dealt with the rotary transformers which run from a L.T. battery. If the apparatus is designed for A.C. operation, then a convenient method of obtaining current at 50 cycles is to use an alternator driven by the engine of the car. One such E.D.C.C. alternator gives 400 watts and is excited from the car starter battery.

Finally, it is frequently found advantageous to employ a wireless generator driven by a small petrol engine. Such an outfit has a special application in a ship's lifeboat and also for telegraph purposes in remote districts. Two typical examples are a Mortley H.F. alternator driven by a small Douglas air-cooled engine and a double-current generator driven by a Stuart-Turner engine.

INSTALLATION AND SERVICING

Location

We will first deal with a D.C. to D.C. rotary transformer such as the M-L Anode Converter. This machine, being enclosed in an aluminium soundproof case, can be placed close to the receiver if desired.

It should always be installed in a horizontal position and on a rigid base. If it is housed inside a receiver cabinet it should be placed on the base and not on a shelf. The box has four Sorbo rubber feet, so should never be clamped or fastened down in any way.

Connecting Up

First remove the lid of the converter by unscrewing the six screws holding same and take out the packing piece fitted between the lid and the top of the rotary transformer. Replace lid, screwing it down firmly. The L.T. terminals of the anode converter should first be connected to the accumulator or, in the case of a private D.C. supply, to a power point in the room in which the machine is installed. Care should be taken to see that the connecting leads are of sufficient cross-section to avoid an appreciable voltage drop in them. Also keep the leads as short as possible.

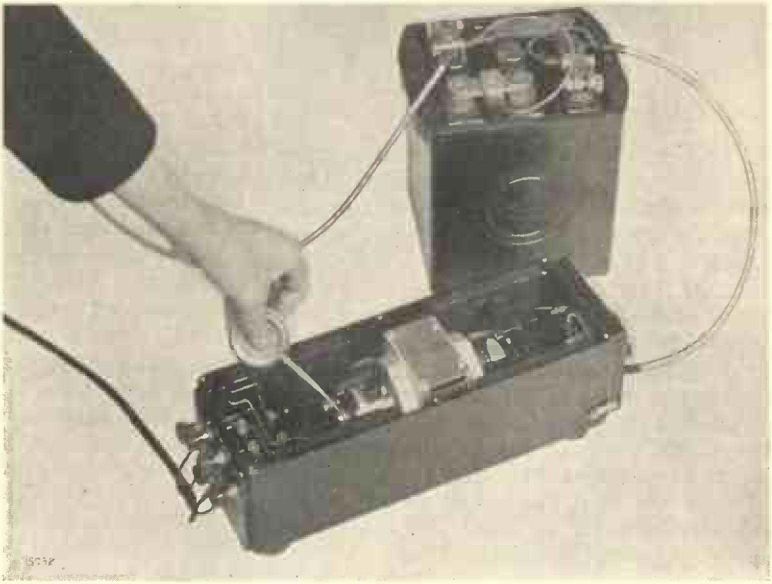


Fig. 6.—Lubricating an Anode Converter.
Two or three drops of thin oil are needed in each bearing about every three months.

The Anode Converter can be treated exactly as a H.T. Battery

Next connect the H.T. terminals of the machine to the H.T. terminals of your receiver. It will usually be found that the machine terminals are marked "H.T.1," "H.T.2," etc., or else with the actual voltages given by the machine, *i.e.*, 150, 100, 90, etc. The anode converter should be treated exactly as a dry battery, and if your receiver has a composite H.T. lead which normally has wander plugs attached this may be used with the anode converter by removing wander plugs and substituting spade terminals. If the machine has grid bias tappings these should be connected up in the same manner. It will generally be found that one common terminal is provided for H.T. negative and positive grid bias.

Switching On

Having connected up in the manner indicated, switch on filaments. Then switch on converter and bring machine up to full speed by means of the rheostat provided (Fig. 5). This rheostat, which has an "off" position, is situated at the L.T. end of the machine. The receiver should now be ready for use.

We have assumed that a separate battery is being used for filament heating. Under these conditions it is usually advisable to earth the negative terminal of the accumulator driving the converter by connecting it to the negative terminal of the filament accumulator. If 6-volt valves are employed and only one accumulator is to be used, separate leads must be employed from the L.T. terminals of the receiver to the battery terminals. It is never permissible to tap across the converter input terminals for filament supply. If 2- or 4-volt valves are used, then the 6-volt battery may be tapped for filament heating between negative terminal and the 2- or 4-volt positive terminal. If the converter input current is not appreciable compared with the filament current, then it will be advisable to change over the cells of the 6-volt accumulator occasionally so that the discharge is equalised. Alternatively, it is usually possible to connect a resistance in the filament lead so that a 2- or 4-volt drop is obtained, and use can then be made of the 6-volt terminals of the battery for both purposes.

CARE AND MAINTENANCE

These machines require very little attention, and one should expect long service without trouble.

The machine should be lubricated in the manner shown in the photograph (Fig. 6). Oil holes will be found at each end of the rotary transformer, and two or three drops of thin oil in each bearing every three months will be ample. A suitable oil is that generally used for the lubrication of sewing machines.

Fitting New Brushes

Brushes will require renewal after about 6,000 to 7,000 hours. The method of carrying out the operation is as follows: First remove machine from box after disconnecting four leads, two each end, held by two B.A. nuts. It will be noticed that the machine rests on rubber feet and is not anchored to the case in any way. Then remove the brush holder of which it is desired to change the brush. This is quite simple: gently push back retaining spring, which acts as one bearing for the pivot pin carrying the brush holder, and at the same time relieve the pressure of the small coil spring which presses on the underside of the bakelite bearing housing. The brush holder will then come away (Figs. 7 and 8). The old brush can then be removed and a new brush inserted, care being taken to see that the correct grade of carbon or copper morganite is employed. The side of the aluminium brush-box should be pinched on to the brush to make sure that it is held rigid.

"Bedding in" a New Brush

The surface of the new brush will be slightly concave, so that care must be taken to see that it is correctly inserted. It will not be "bedded in," however, and this should be carried out after the brush holder has again been assembled on the bearing housing. Place a thin strip of carborundum cloth around the surface of the commutator with the abrasive surface upwards and carefully rotate the armature to and fro through a few degrees, with the brush pressed on to the carborundum. The brush surface will thus take the correct curvature. The machine should be given

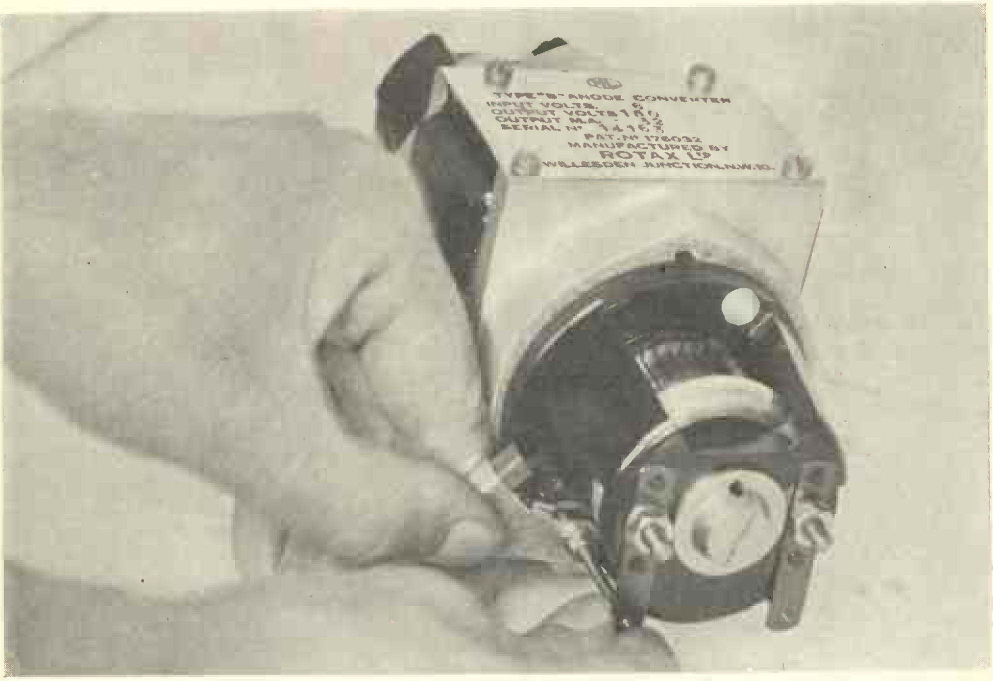


Fig. 7.—REMOVING A BRUSH HOLDER OF AN ANODE CONVERTER.
Showing the retaining spring being gently pushed back.

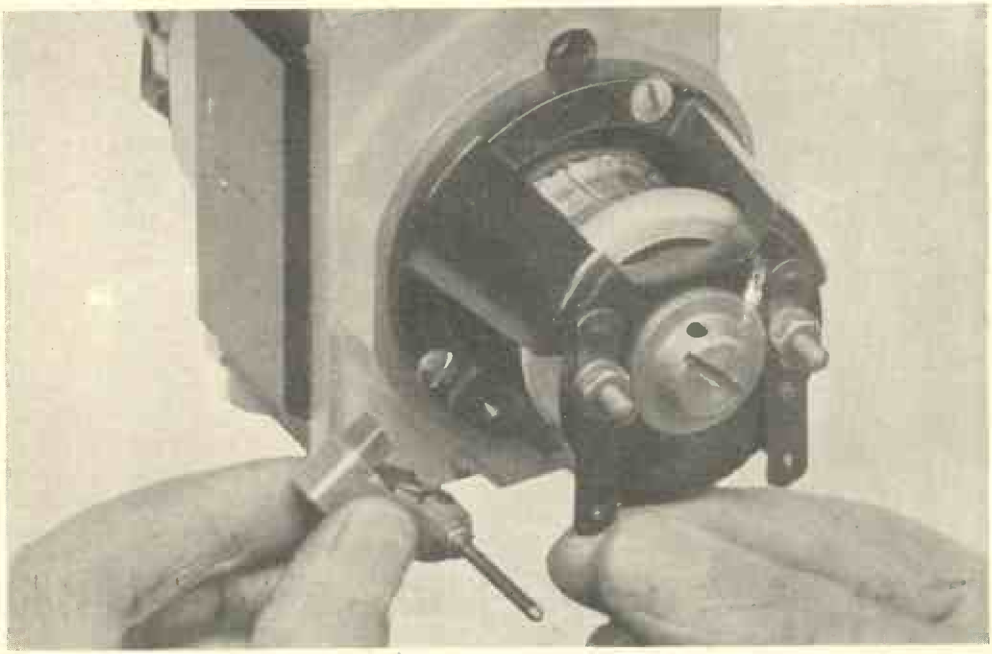


Fig. 8.—REMOVING A BRUSH HOLDER OF AN ANODE CONVERTER.
This shows the brush holder being lifted out.

a run of an hour or so on open circuit after the fitting of a new brush.

Cleaning of Commutator

It will probably be found that after a run of one hour the commutator has blackened somewhat, and use should then be made of a small tool (usually provided by the makers) called a "commutator cleaner." This consists of a fine carborundum cloth pad of correct radius to suit commutator, and it should be gently applied, as shown in illustration (Fig. 9).

Fig. 9.—Cleaning the Commutator of an Anode Converter.

This will have the effect of polishing the commutator, which will not blacken again if the brush is properly "bedded in."

FAULT FINDING

(1) If Low Output Voltage is Suspected

Switch on the valve filaments and the anode converter. By means of a L.T. voltmeter measure the voltage directly across the input terminals of the machine. If this is lower than the rated input voltage of the machine, check the voltage either across the accumulator terminals or, in the case of machine operating from lighting plant, across the wall plug. If this reading corresponds with the rated input voltage, then it is obvious that there is an appreciable voltage drop in your input leads. These should be shortened if possible, and, in addition, leads of greater cross-section should be employed. If, however, this reading is also low, then the accumulator is partially discharged and should be immediately recharged. In the case of the country house plant the charging dynamo should be started.

Testing the Output Volts

Having made perfectly certain that the machine has the correct voltage across its input terminals, test the output volts by using a high-resistance voltmeter (one having a resistance of 200 ohms per volt will be suitable) (Fig. 10). If this is lower than the rated output voltage, then the output current should be checked by connecting a milliammeter in series with the negative output lead. If this shows a current in excess of that shown on the plate on top of the anode converter it is obvious that either your valves are incorrectly biassed or that you are using too small a machine. You can easily determine what your total milliamperes should amount to by consulting a valve data sheet, which will also tell you the correct bias for each valve.

Fault in the Armature

If your milliamperes are within the specified figure, then it is obvious that there is a fault in the armature, and it will usually be best to return the machine to the makers for examination. To the skilled armature winder the location of the fault, probably an open circuit in the armature, would present no difficulty. The machine, however, being of the permanent magnet type, would require remagnetising after the armature had once been removed. Otherwise it would attain an excessive speed and cause a certain amount of mechanical noise. Therefore, unless one is in possession of a fairly powerful magnetiser, it would not be wise to tackle the job.

(2) If Receiver will not Function and it is found that there is no Voltage across Output Terminals of Converter

This may be due to one of two causes. Either (*a*) there is a break in the H.T. choke coil or in one of the connections between the choke and the output terminals, or (*b*) one of the condensers in the smoothing circuit has failed, causing a short circuit of the output. The former is proved if a voltmeter reading taken across the actual machine output terminals shows normal volts. If an ammeter connected in series with one of the input leads shows an abnormally high current flowing from the battery, then a condenser should be suspected, and it is advisable to disconnect each one in turn until input current drops to normal.

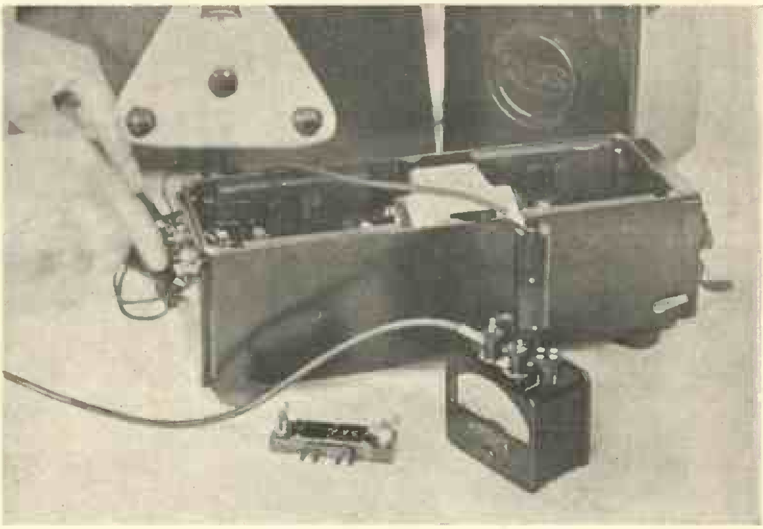


Fig. 10.—Testing the Output Voltage of an Anode Converter.
(The instrument shown is an Ernest Turner Volt-Ammeter Model 55.)

A new condenser, which should have been tested at at least three times the working voltage, should be fitted, and this is a simple operation to perform.

(3) If there is a Noisy Background in your Loud Speaker

If there is a "crackle" or "frying" noise present in your loud speaker and the machine is suspected, you can make sure by substituting a new dry battery for the converter. If the noise is still apparent, it is obvious that this is emanating from some outside source, and an investigation should be carried out to see whether there are any fans, lift motors, etc., in close proximity. Trouble due to these can often be eliminated or considerably reduced by the connection of some form of anti-interference device across the brushes. Two condensers in series with centre point to earth is a useful remedy in such instances.

Try Removing the Aerial

Should the substitution of the dry battery cure the trouble, then it is conclusive that the converter is responsible. The aerial should be disconnected, and if interference then vanishes it is due to "pick up" from the converter or input leads. The earth connection to the receiver and to the converter case should be examined, and if the machine is running on a private D.C. supply care should be taken to see that the lead covering of the wires is itself joined to a good earth.

What to do if this does not remove Interference

If the removal of the aerial connection does not remove interference, then it can be due to one of three things—there is sparking at one of the H.T. brushes; there is a fault in the choke, or an intermittent short circuit in one of the smoothing condensers.

The first of these faults may be due to a dirty commutator and use should then be made of the "cleaner" previously mentioned.

In the case of the second and third faults mentioned it is wise to change the components, since the choke may have an intermittent break in its winding which might be extremely difficult to discover.

An anti-interference or filter device is mounted by the side of the machine. The metal cover fits on a strip of sponge rubber fastened round the outer edge of the baseboard and is held in position by four bolts and wing nuts.

When mounted in this manner the running of the machine is practically inaudible, and it is possible to instal it in the same room as the loud speaker without discomfort. This is, of course, advantageous from the point of view of electrical silence (*i.e.*, absence of background noises in loud speaker), since long D.C. and A.C. leads, unless carefully wired, can cause a certain amount of trouble. One of these troubles is sometimes apparent when it is necessary to run D.C. and A.C. leads parallel for some distance in order that the machine may be switched on by means of a switch near the receiver.

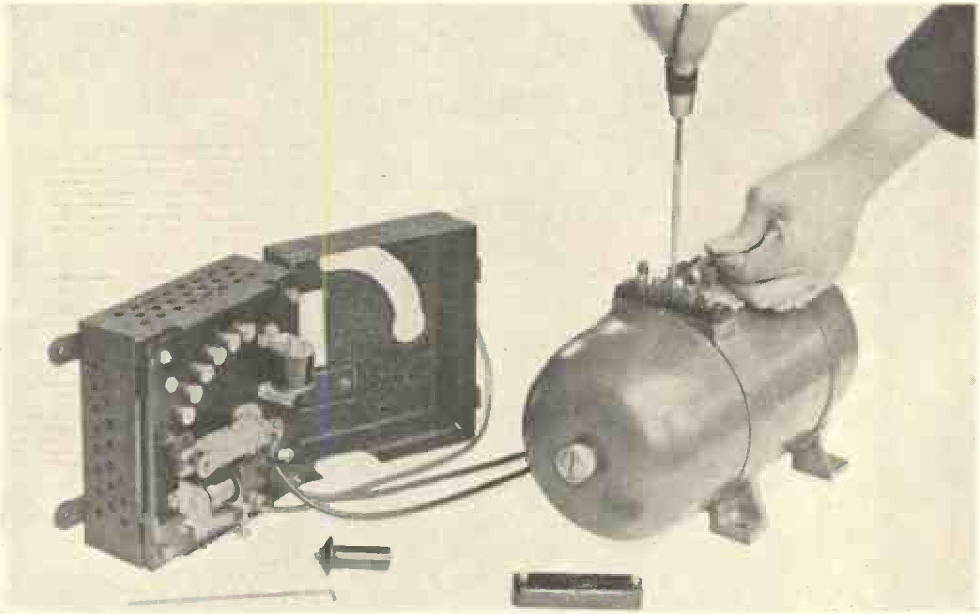


Fig. 11.—Connecting a Starter to an M-L 200-watt D.C. to A.C. Rotary Transformer (*Rotax Ltd.*).

The machine is shown without anti-interference unit and soundproof cover.

INSTALLING A D.C. TO A.C. ROTARY TRANSFORMER

Nowadays a majority of the D.C. to A.C. rotary transformers on the market are supplied with a sound-proof cover. The machine is mounted on a wooden baseboard, liberal use being made of sponge rubber both underneath and on top of the machine, which is held down by a fixing strap. It is therefore well cushioned, ensuring that a minimum of vibration is transmitted to the baseboard.

When it is not found possible to house the machine close to the receiver it may be installed in any dry place, such as a cupboard, a cellar, an outhouse or a garage adjoining the house. In such cases it is a good plan to wire the A.C. leads from the machine to the receiver and the D.C. leads to the operating switch by different routes into the room where the receiver is installed. Lead-covered wire should always be used for connecting purposes under these circumstances. It is advisable to see that the lead-in of the receiver is kept as far as possible from all D.C. leads. Owing to the varying nature of D.C. supplies and earthing systems, it is not possible to lay down stringent laws with regard to earthing the covering of the leads. Sometimes it is found best to earth this by employing a separate earth lead entirely from that of the receiver. Sometimes earthing this covering brings in a certain amount of interference.

Switching

Rotary transformers up to 100 watts capacity can be switched on to the mains by means of an ordinary tumbler switch. For machines larger than this the use of a hand-operated starter with no-volt and overload releases is to be recommended. This reduces the starting current and is particularly useful when one is dealing with private D.C. supplies of small capacity. Furthermore, if a machine is being switched " on " and " off " a good many times a day some damage to the machine may occur if a starter is not employed.

Connecting Up

This is quite a simple operation. Dealing with small machines, first of all the D.C. mains should be wired up to the input terminals of the machine. Connect a tumbler switch in series with one of the leads. Then connect the output terminals of the machine to the flexible lead from the receiver which is normally connected to the mains supply. We have assumed that the machine in question is already connected up with the anti-interference device. If, however, this is not the case, the filter should be connected up and the terminals of this unit are usually plainly marked. The M-L Anti-Interference Unit has five terminals, two marked " A.C.," two marked " D.C.," and one marked " E." The two former should be connected across the output terminals of the machine, the next two across the input terminals and the " E " terminal to a good earth.

The E.D.C.C. Filter has eight leads attached which are marked. Four of these are joined to the four terminals of the

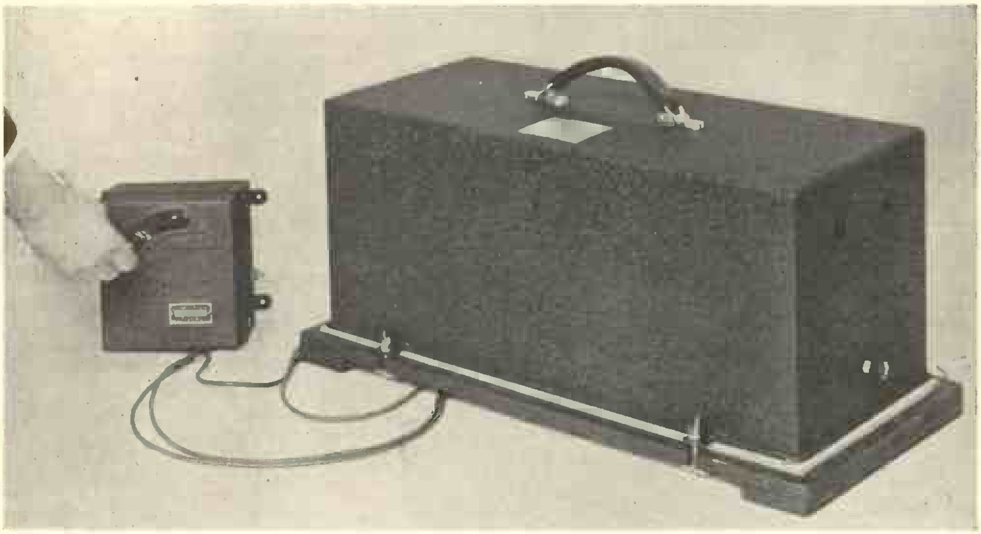


Fig. 12.—OPERATING THE STARTER TO START A LARGE D.C. TO A.C. ROTARY TRANSFORMER.
Close the tumbler switch and draw handle of starter slowly over the studs. Release the handle when the last stud has been reached.

machine, two of the others going to mains and two to receiver. When connecting up an E.D.C.C. Converter therefore the mains will not be joined direct to the machine, but to the input leads of the filter unit, whilst the receiver will be connected to the output leads of the filter.

Use of Starter

If a starter is employed, the connections on the input side should be as follows :—

Join mains to " L " terminal of starter and to " L " terminal of machine. Join " A " and " Z " terminals of starter to the terminals on the machine marked " A " and " Z." In case terminals of machine are not marked, " A " is joined to one brush holder, " L " to the other brush holder and one side of the field and " Z " to the other side of the field (Fig. 11). It is advisable to employ a tumbler switch in line circuit, as with smaller machines.

To Start Large D.C. to A.C. Rotary Transformer (Fig. 12)

Close tumbler switch and draw handle of starter slowly over studs. When the handle has reached the last stud it can be released and it will be held in a vertical position. To stop machine, merely open tumbler switch and the starter handle will fly back to " off " position.

To Test the Output of a D.C. to A.C. Machine

This should be carried out as follows :—

Check up the voltage across the input terminals of the machine. This should correspond approximately to the voltage marked on the name plate of the transformer. If this is found to be more than 10 per cent. lower than your D.C. mains voltage, either there is a serious drop in volts between your mains plug and the machine or your supply is below its normal voltage. Test the voltage across the wall plug to see which assumption is correct. It is usual for radio receivers and radio gramophones to be designed to operate from A.C. supplies of 200–250 volts, 50 cycles, and in some instances from 100–120 volts, so that it is not absolutely essential for the output voltage to be exactly 230 volts or 110 volts, which are usually the voltages which the machines are designed to give on full load, and accordingly a 10 per cent. drop in mains voltage can usually be tolerated, provided that the figure is likely to remain constant.

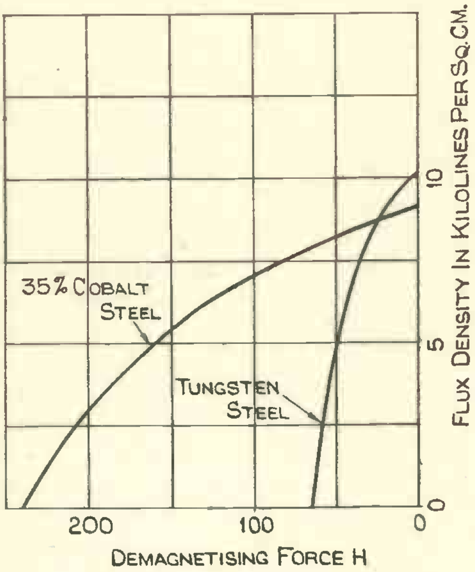


Fig. 13.—Magnetic Data for Tungsten and 35 per cent. Cobalt Steels.

Next, test your output voltage with the receiver switched on. When taking this reading it is advisable, if any doubt exists as to whether the receiver consumes the full output of the machine, to employ the 250-volt tapping on the mains transformer and gradually to work down these tappings until the voltmeter is reading the voltage of the tapping to which the machine is connected.

What to do if Output Voltage Falls Below Rating

If the output voltage falls below rating with the D.C. input volts correct, then it is apparent that either the machine is being overloaded or that there is a fault in the secondary winding. Connect an A.C. milliammeter (0 to 500 milliamperes model will usually be suitable) in series with one of the output leads, and if the reading is more than the rated output current of the machine, then same must be considered too small to operate the receiver in question.

What to do if Machine Refuses to Start

If the machine refuses to start and blows a fuse in the input leads, it is obvious that there is a short circuit in the A.C. circuit. This may be due to a condenser in the anti-interference unit or to some fault in the receiver. Disconnect the unit, and if the machine now starts a new unit should be fitted. If, however, the machine still refuses to function, a careful examination of the receiver should be carried out.

Interference in the Loud Speaker

In the event of interference being present in the loud speaker, first examine the commutator and see if there is any sparking taking place at the brushes, having of course previously ascertained that the machine is actually responsible. The commutator may require cleaning or brushes may require renewal. Always look to the earthing system when cases of trouble arise.

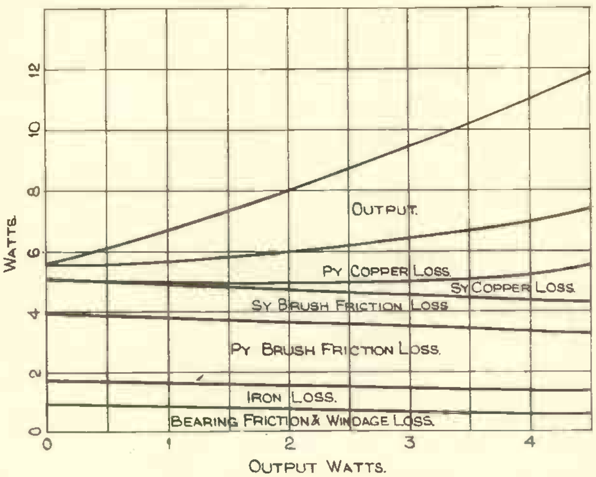


Fig. 14.—Curves showing the Separation of the Losses in a small Rotary Transformer giving 30 m.a. at 150 volt D.C.

NOTES ON THE DESIGN OF ROTARY TRANSFORMERS

The design of radio power plant involves problems not usually associated with large commercial rotary transformers and converters. In the first place, since these machines often have to run from low-voltage D.C. supplies, such as 6- or 12-volt accumulators, it becomes extremely important to obtain as high an efficiency as possible. Very often therefore field windings usually associated with electrical machines are dispensed with and a permanent magnet is employed to provide the flux.

The use of a permanent magnet for such a purpose has been made possible by the introduction of cobalt steel. This steel was first used for high-tension magnetos just after the war in place of tungsten steel, and has several outstanding advantages.

What happens when a Piece of Steel is Magnetised

To investigate these advantages one must consider what happens when a piece of steel is magnetised.

Imagine this piece of steel placed inside a coil and a direct current passed through the coil. The lines of force produced by the ampere turns of the coil cause lines to be produced in the steel, and if the current is increased to such a value that further increase will not cause any more lines to be formed, the steel is said to be "saturated." If the current flowing in the coil (called the magnetising current) is then reduced to zero, the lines of force or magnetic flux in the steel do not fall to zero, but the steel retains a certain amount of magnetism, this being called the remanence or remanent flux.

Now if the direction of the current in the coil be reversed and its value gradually increased, this residual magnetism will be reduced to zero. The demagnetising force or ampere turns required to produce this result is termed the coercive force of the steel.

Advantage of Cobalt Steel

Now the great advantage of cobalt steel is that whilst it has a remanence equal to that of tungsten steel it has a coercive force of about four times that of tungsten steel (Fig. 13).

This latter property makes it possible for a machine to be designed with about a quarter of the magnet length necessary with tungsten steel to obtain the same results. (Readers will remember the pre-war magnetos, with a long horseshoe magnet, and compare the present-day types with short bar magnets.)

It will be seen therefore that the use of cobalt steel makes it possible for a compact machine to be made, and the elimination of the field copper losses means an increase in efficiency. As light weight and minimum overall dimensions are important factors when designing radio power plant, it will be realised what a boon the introduction of this steel has been to the designer.

Wound fields are favoured by some designers, even for machines wound to run from L.T. batteries, and these have one advantage: that they are fairly cheap to produce.

Fig. 15.—Withdrawing a Brush from a 100-watt D.C. to D.C. Rotary Transformer.

Note the two commutators.

A Permanent Magnet Rotary Transformer

A permanent magnet rotary transformer, as previously stated, consists of a double-wound armature revolving in a magnetic field provided by a cobalt steel magnet. In order to reduce friction losses, ball bearings are invariably employed, and although plain bearings are somewhat quieter mechanically, they cause a bigger friction loss, and, in addition, require very careful lubrication.

The Armature Core

The armature core is laminated, *i.e.*, it is built up of stampings made from sheet iron such as Stalloy, these stampings having a coating of insulating varnish on one side. The stampings are keyed on to the shaft, and this construction tends to prevent the formation of circulating or "eddy" currents in the core. Pole shoes are also laminated in the case of the small permanent magnet and wound field rotary transformer, but in larger permanent magnet machines iron pole shoes are often dispensed with, a cast cobalt magnet and pole shoes being employed. This effects a big reduction in ripple and will be mentioned later.

Design of Brush Gear

The design of brush gear is an important factor. The box type of brush holder or the pivoted type are generally employed. The brush pressure has to be carefully adjusted. Too light a spring pressure means a chattering brush, a fatal fault when a machine is to be used for radio purposes. On the other hand, too much brush friction means increased current consumption and brush and commutator wear. The grade of brush fitted depends of course on the current to be carried and the permissible voltage drop across the brush. A high-resistance brush assists commutation.

For machines to operate from 6 or 12 volts it is necessary to employ a low-resistance, high-conductivity brush of the copper morganite type (Morgan Crucible Co.). Since these brushes carry fairly heavy currents, it is usual to employ a flexible or pigtail to carry the current from the brush to the terminal instead of the brush spring, which would lead to the softening of same. It is usual for brushes of this grade to run on commutators with undercut mica.

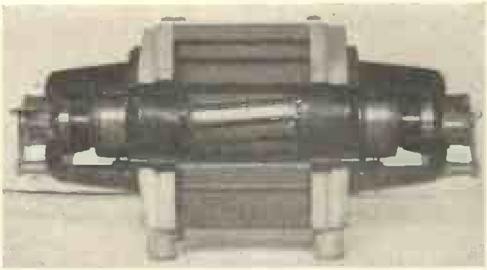


Fig. 16.—SECTIONAL VIEW OF PERMANENT MAGNET ROTARY TRANSFORMER.

Showing laminated pole shoes, skewing of slots, etc.

How Good Commutation is Obtained

To secure good commutation at the H.T. output commutator a hard graphitic carbon brush is employed, the commutator micas usually being flush with the copper.

Dealing with the commutators themselves, a common practice nowadays is to build up the mica and copper segments in a ring and mould in bakelite.

An interesting set of curves is given in Fig. 14, which shows the separation of the losses of a small rotary transformer giving 30 miliamperes at 150 volts. The curves are self-explanatory, but they do show that when dealing with a small machine there are no load losses which become large compared with the output, and therefore it is extremely difficult to show a high efficiency.

An interesting construction in connection with some of the larger rotary transformers on the market is the fitting of input and output commutators at the same end of the armature. This not only makes it possible for a cooling fan to be fitted at the opposite end, but makes the brush gear more accessible, since both sets can be inspected through one window (Fig. 15).

Fig. 17.—CAST COBALT STEEL MAGNET.
Note the ribbed construction.

Eliminating Ripple

We have now come to the most important consideration in the design of these machines, the minimising of the ripple superimposed on the output. It will be realised that this must be reduced to such a value that a silent background is obtained in the loud speaker. Smoothing apparatus will, of course, have to be employed, but a designer must aim at reducing the ripple volts across the machine output terminals to a minimum so that the final smoother shall not be unwieldy.

Why as Many Slots and Commutator Bars as Possible are Used

The first step is to employ as many slots and commutator bars as possible so that any ripple produced will only be a small percentage of the total voltage generated. The actual number of slots and bars is of course limited by considerations of size and cost. Generally speaking, small rotary transformer armatures up to 200 watts capacity carry 19 to 23 slots, and commutators for these machines have 19 to 69 bars. In order to provide for the gradual entry of the conductors into the magnetic field, the slots in the armature core are skewed. The best angle of skew is found to be one slot pitch, and a large reduction of ripple is effected by these means (Fig. 16). The pole tips are bevelled to give the correct flux distribution and cores are ground to ensure an even air gap, both these operations causing a diminution of the ripple.

Tracing of Ripple

The tracing of ripple associated with a machine often leads to some unexpected sources of trouble. For instance, a small hole situated at the bottom of one tooth of each stamping of an armature proved to be responsible for considerable ripple. Another cause of ripple is, of course, flux change in the pole shoes. Short-circuited copper damping bars embedded in the pole shoes lead to a reduction, but it has been found that the employment of a cast cobalt steel magnet and pole shoes (Fig. 17), as previously mentioned, will improve a machine even further.

This is the type of magnet employed on many of the rotary transformers of 60 watts capacity and over. It will be realised that with a magnet of this type it is impossible for a flux change to occur in the pole shoes. The ribbed construction of this magnet is interesting, this being to ensure an even cooling when the magnet is hardened, so as to prevent the formation of soft portions which will detract from the magnetic value of the magnet.

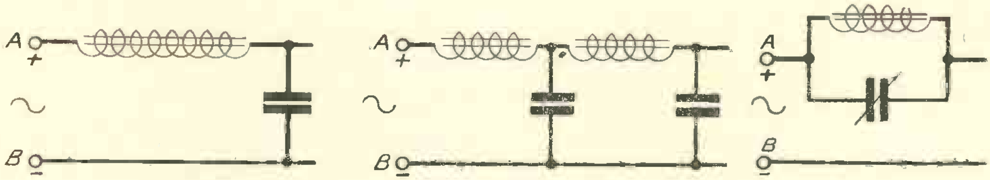


Fig. 18.—Different Types of Smoothing Circuits.
From left to right: "Brute Force" type; two Smoothers in tandem; Tuned type.

Smoothing Apparatus

Having arrived at a design producing minimum ripple across the output terminals, one must then consider the best type of smoother to be employed. Ripples of 2 or 3 per cent. may be expected with well-designed machines, and this would need to be considerably reduced to give an output smooth enough for radio reception (it should be noted that a small ripple on the anode of a H.F. valve may become an annoying hum in the loud speaker in a receiver having large H.F. amplification).

Ripples associated with small rotary transformers are of a number of different frequencies, and therefore the tuned type of smoother, which definitely eliminates ripples of any given frequency, is scarcely ever employed. Use is made of what is termed the "brute force" smoother, in which one employs as large an inductance as possible, and follows this with a condenser of maximum capacity (Fig. 18). Ripples of any frequency are thus reduced to a minimum without attempting to eliminate ripples of any particular frequency.

Smoothing Chokes

A choke for use in a smoothing circuit consists of a coil of copper wire wound on a laminated iron core. The core will form practically a complete magnetic circuit, there being only a very small air gap. To understand the action of a choke let us consider what happens when a varying current flows through the coil of the choke. This varying current causes variations in the number of lines of force embracing the coil, and this change in flux links with the turns of the coil and produces a back electromotive force in the coil. This back E.M.F. or voltage tends to oppose the current producing it.

In the smoothing choke the varying current is, of course, the ripple superimposed on the D.C. output of the machine, and the choke, by virtue of its inductance (*i.e.*, the change in lines for unit change in current multiplied by the total turns), offers impedance to the ripple. Since the lines produced are also proportional to the number of turns on the coil, it follows that the inductance of a choke is proportional to the square of the number of turns.

A point to watch in connection with smoothing choke design is effect of the D.C. component on the total lines embracing the coil. Obviously saturation of the core must be avoided, otherwise the change in lines produced by the ripple will be negligible and the choke will have no inductance. The introduction of the air gap in the iron circuit is made to prevent this saturation when a choke has to carry a heavy D.C. component. Needless to say, the D.C. resistance of the choke should be as small as possible to prevent voltage drop.

Condensers

Condensers for smoothing purposes may be from 1 to 8 m.f.d. in capacity. They are usually of the paper dielectric type. The condenser, by virtue of its low impedance, readily absorbs any remaining ripple, and it can be proved that the higher its capacity the lower its impedance and consequently the greater its ripple-absorbing power.

When designing a smoothing circuit, employ a condenser tested at about three times the voltage given by the machine. For instance, if you desire to smooth a 200-volt D.C. supply, employ a condenser tested at 600 volts D.C.

Condensers for use overseas should always be of the special tropical type manufactured by most of the leading condenser firms.

Smoothing Ratio

It can be shown that the smoothing ratio of such an arrangement is w^2L.C., where w is $2\pi f$ (f being the frequency of the ripple), L. the inductance of the choke in henrys and C. the capacity of the condenser in farads. Assuming a frequency of 630, which would be the slot ripple of a machine having 19 slots and running at 2,000 r.p.m., a typical value of the smoothing ratio would be 5,000 to 10,000, which means that an original ripple of 2 per cent. would be reduced to a ripple of ·0004 per cent. or ·0002 per cent.

When two smoothers are connected in tandem the resultant smoothing ratio is the product of the smoothing ratios of the separate smoothers, so that under some circumstances it is advantageous to employ two smoothers having components of small values in tandem rather than the use of larger components in a single smoother. In one of the well-known rotary transformers on the market a smoothing condenser is connected across the output terminals of the machine, so that a smoothing circuit in tandem with the smoother following is formed, the inductance being that of the armature winding.

L.T. Choke

It should be noted that when using a battery-fed rotary transformer operating from the same accumulator as that which heats valve filaments it is always necessary to connect a choke in the input leads between the accumulator and machine.

In commercial form small rotary transformers as above mentioned are supplied with H.T. smoothing circuit and L.T. choke. In addition, an anti-interference device is often fitted.

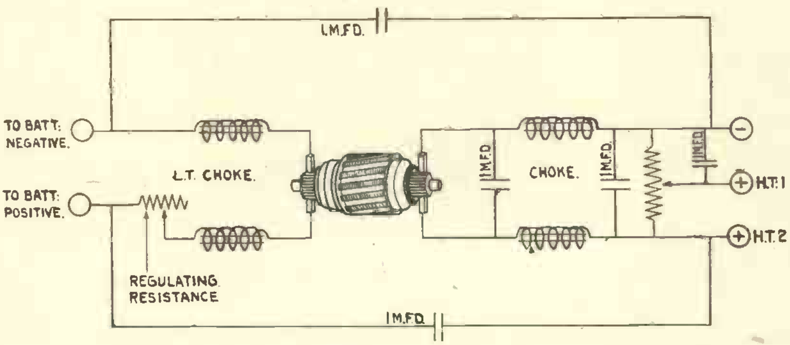


Fig. 19.—Diagram of Connections of M-L Anode Converter. Note the L.T. choke.

Filter or Anti-Interference Devices

These are, of course, necessary when D.C. to A.C. rotary transformers are used for radio purposes, although they are not required when machines are only being used with L.F. amplifiers.

They consist of condensers and, in some cases, H.F. chokes arranged in such a manner as to prevent H.F. disturbances from the machine getting into the input and output leads, from whence they would be radiated and picked up by the aerial system.

By employing these units condensers are connected in series across the input terminals with the centre point joined to earth and in a like manner across the output terminals.

SERVICING

THE MARCONIPHONE RADIO RECEIVER MODEL 42 FOR A.C. MAINS

General Arrangement

A THREE-VALVE radio receiver with screened-grid Marconi MS4B high-frequency valve, Marconi MH4 detector valve, and Marconi MPT4 mains pentode output valve.

Loud Speaker

Marconi low-resistance permanent-magnet moving coil.

Fig. 1.—THE MARCONIPHONE 42 MODEL.

Pick-up Arrangements

Sockets are provided for the insertion of leads from a high-resistance pick-up, the volume control of the instrument operating on the pick-up without the need of an external volume control.

HOW THE INSTRUMENT WORKS

Reference should be made to Figs. 2, 3 and 5 when the notes below are referred to, as it will be noted that the component markings on the theoretical diagram, Fig. 2, correspond to the illustrations of the actual components themselves in Figs. 3 and 5, this arrangement enabling the fault finder to locate any component without the necessity of tracing wiring.

Mains Aerial Device

By the insertion of a plug in the aerial socket, the aerial coil is connected to the mains by the condenser C19 (·0001 mfd.), thus employing the mains wiring as an aerial.

THE WAVE CHANGE "ON-OFF" SWITCH

"Off" Position

In this position the mains supply is disconnected from the mains transformer by the mains switch (S6, Fig. 3).

"MW" Position

Long - wave coils, L2, L4 and L6, are short circuited out by the contacts "c b"—"b a" and "h g" respectively.

"LW" Position

In this position the switch contacts mentioned above are opened, allowing the long-wave coils to function in series with their respective medium-wave coils, L1, L3 and L5.

THE TUNING CONTROL

A right-angle cord drive operating the 3-ganged condenser VC1 (tuning aerial circuit), VC2 (tuning grid circuit of H.F. valve), and VC3 (tuning grid circuit of detector valve).

Aerial Trimming Condenser (see Fig. 6)

The signal from the aerial is fed through the variable coupling condenser VC4 which in addition to providing exceedingly fine tuning, enables the selectivity of the instrument to be varied.

Note.—This condenser should be entirely disconnected from the frame of the unit

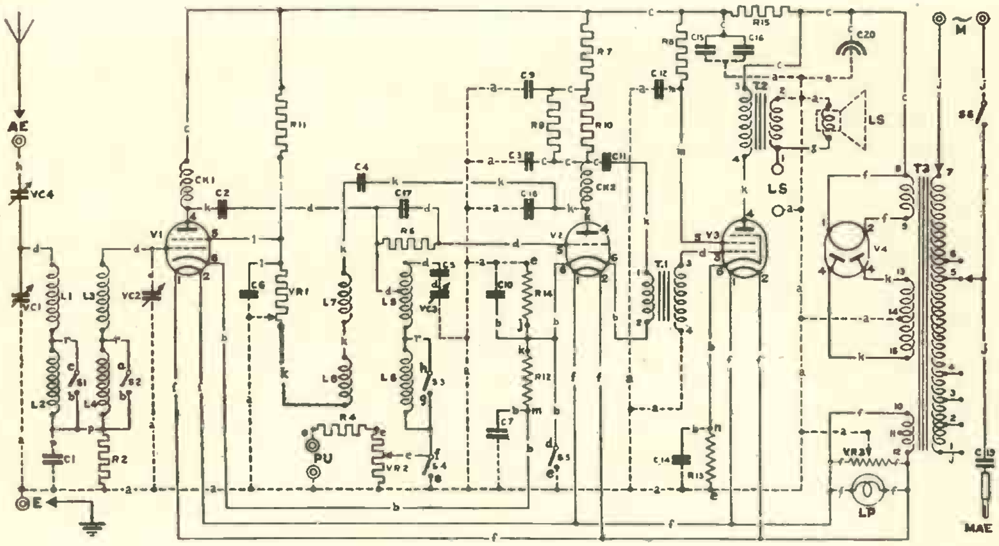


Fig. 2.—Theoretical Diagram of Marconiphone 42 Model.

by black insulating washers. A complete failure of radio may be due to a cracked or faulty washer.

The Reaction Control

This control operates for controlling radio volume by a variable 50,000 ohm resistance (VR1), which in the position of minimum resistance (min. volume), by-passes the screen current of the H.F. valve to earth and inserts its maximum value of resistance between the earth end of the reaction coils L7 and L8, thus simultaneously reducing the sensitivity of the H.F. valve and limiting the effect of the reaction coils L7 and L8, which are wound on the same former as the grid coils of the detector valve (L5 and L6, see Fig. 5).

Pick-up Volume Control (see Fig. 8)

This variable resistance ("VR2"—25,000 ohms), is mounted on the same shaft as the radio volume control. When the switch is in the gram position, signals from a pick-up connected to the blue pick-up sockets pass *viâ* resistance R1 and are applied across the "outers" of VR2. Switch contacts "f" and "e" are opened and pick-up signals are applied to the grid of the detector valve *viâ* coils L6, L5, and grid leak and condenser R6 and C17. Simultaneously, switch contacts "d" and "e" open and allow bias dropper R4 to operate between the cathode of the MH4 detector valve and earth, thus applying suitable bias to the detector valve to enable the valve to operate correctly as a low-frequency amplifier.

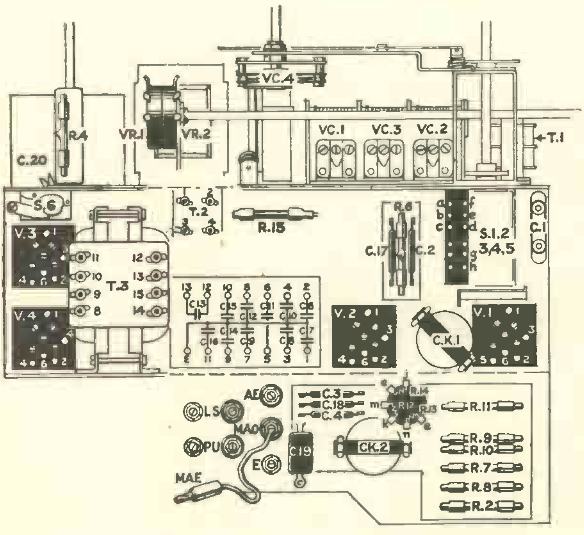


Fig. 3.—Layout of Plan of Components.

HIGH-TENSION SUPPLY TO VALVES

A Marconi "U10" full-wave rectifying valve is employed, which receives across its anodes the voltage of the high voltage secondary winding of the mains transformer T3 from lugs 13 and 15 (yellow wiring). Lug 14, the centre top of this winding, constitutes the H.T. negative lead, and is connected to the frame of the radio unit and earth (dotted line, Fig. 2). The D.C. resistance of the high-voltage winding is approximately 1,250 ohms.

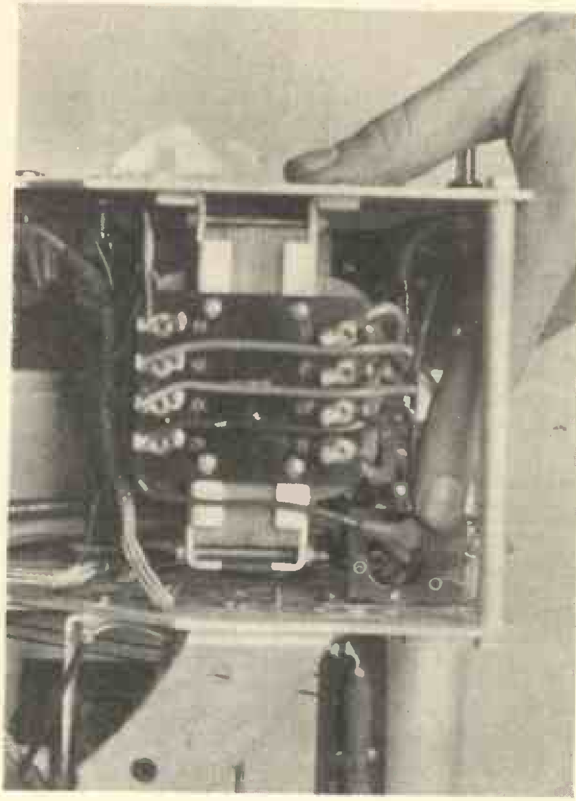


Fig. 4.—The Mains Aerial Condenser, C.19.

The filament of the U10 is fed with 4·0 volts A.C. from a special filament winding lugs 8 and 9 (D.C. resistance approximately $\frac{1}{4}$ ohm—measured with the valve *out*).

High-tension D.C. is fed from a filament of the rectifier valve holder *viâ* socket (a red wire at approximately 380 volts to the smoothing circuit).

High-Tension Smoothing Circuit

Resistance smoothing is employed with condensers, the main smoothing resistance being R15 (20,000 ohms). Smoothing condensers are C15 (4 mfd.), C16 (4 mfd.) and C20 (8 mfd.). C20 is an electrolytic condenser, and for this reason should be correctly reconnected if removed for examination.

ADJUSTMENT OF VOLTAGE TO PARTICULAR VALVES

Anode

The pentode valve receives full high-tension positive unsmoothed by R15 (20,000 ohms.). All other valves receive high tension *viâ* R15 and individual voltage dropping resistances.

Pentode Screen

The voltage to the screen is reduced from the main high-tension voltage to approximately 150 volts (valve in) by voltage-dropping resistance R8 (10,000 ohms) passing to the flexible screen connection *viâ* a yellow-and-black wire and one side of a smoothing condenser, C12 (1 mfd. lug 8 in condenser "can"), the other side of which is connected to earth inside the "can."

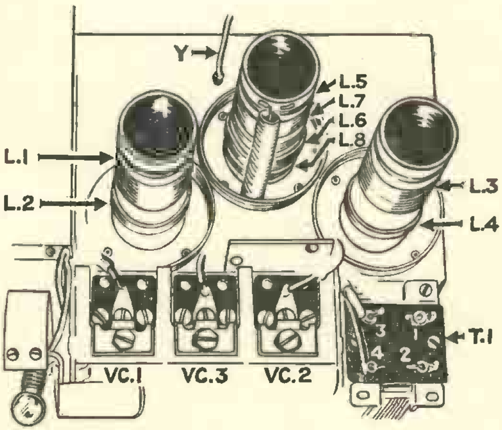


Fig. 5.—Details of the Coils.

RAPID CHECK CHART FOR HIGH-TENSION VOLTAGES OF VALVES

VALVE.	CORRECT VOLTAGE WITH VALVE IN	CHECK CONTINUITY OF:—	LOOK FOR LEAKAGE TO EARTH IN:—	NOTES.
Marconi MS4 B Screen-grid H.F. Valve ANODE.	150 volts	H.F. choke CK1 (85 ohms) to red wiring to R15, and C20 (8 mfd.) (20,000 ohms) *Note.*—A higher voltage suggests low-emission valve or R12 (650 ohms) or R15 (1,000 ohms) burnt out.	Condensers: C2 (to L5 and 6 and earth). Condenser C15 (lug 10 in "can"). Condenser C16 (lug 11 in "can"). Condenser C20 (lug 1).	Vol. Cont. should be full on (clockwise).
SCREEN.	45 approx.	Red and yellow wire to (100,000 ohms). R15 (20,000 ohms).	Condenser C2 (·0005) (to E *viâ* Coils L5 and 6). Condenser C15 (4 mfd. lug 10 in "can"). Condenser C16 (4 mfd. lug 10 in "can"). Connections of UR1 (500,000 ohms).	
Marconi MH4 Detector Valve. ANODE.	Approx. 70 volts (Valve in)	Yellow wire H.F. choke CK2 (D.C. 85 ohms). Red wiring, R9 and R10, (100,000 ohms each in parallel). R7 (10,000 ohms). Red wiring R15 (20,000 ohms). *Note.*—Higher voltages suggest low-emission valve or R12 or R14 burnt out.	Condenser C18 (·0002 mfd.). Condenser C4 (·0002) and yellow wire to coils L7 and L8 and volume control UR1 to E. Condenser C3 (·001 mfd.). Condenser C9 (1·0 mfd. lug 7 in "can"). Condenser C2 (·0005 and as above).	
Marconi Pentode MPT4 Output Valve ANODE.	280 volts (Valve in)	Yellow wiring. Primary of output Transformer ("T2" D.C. Resistance 1,000 ohms). *Note.*—Low volts suggest low-emission valve or R13 (280 ohms) burnt out.	Condenser C20.	
SCREEN.	150 (Valve in)	Yellow and black wire. R8 (10,000 ohms).	Condenser C12 (1·0 mfd. lug 8 in "can").	

Detector Anode High-Tension Circuit

The voltage supply to the anode of this valve is reduced to approximately 70 volts by dropping resistance R7 (10,000 ohms) and resistances R9 (100,000 ohms) and R10 (100,000 ohms), which are connected in *parallel* and constitute the coupling resistances to the intervals transformer "T1" *viâ* coupling condenser C11 (·5 mfd. lugs 5 and 6 in the main condenser "can").

High-Frequency Valve Anode High-Tension Supply

The voltage supply to this anode is fed directly from R15, the main smoothing resistance, *viâ* the high-frequency choke, CK1 (approximately D.C. resistance, 85 ohms).

Screen Voltage of High-Frequency Valve

This voltage, which is affected by the volume control VR1 (measure voltage with this set fully clockwise), is reduced to 40 volts by voltage-dropping resistance R11 (100,000 ohms), and fed by a red and yellow wire to the screen socket of the valve holder.

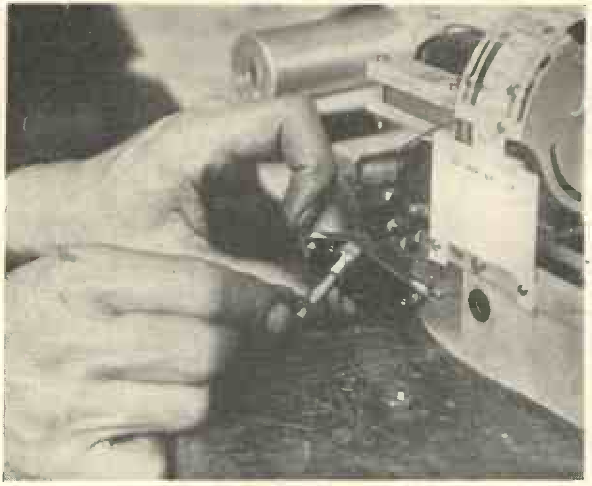


Fig. 6.—The Aerial Trimmer Condenser.

If a failure on radio occurs, examine the insulated washers on the spindle of the condenser.

HOW TO TAKE OUT THE RADIO UNIT (see Figs 9, 10 and 14)

Note.—When ordering spare parts or corresponding, the chassis number, which will be found on an aluminium plate on the top of the chassis near the U10 valve holder, MUST be quoted in addition to the serial number of the instrument.

(1) Remove valves and put in safe place.

(2) Remove control knobs.

(3) Remove moulded volume control plate. (See Fig. 9.)

(4) Remove four chassis-retaining screws from bottom of cabinet (do not loose nuts and washers for two back screws). (See Fig. 10.)

(5) Cut loud speaker leads close to tags. (See Fig. 11.)

(6) Slide chassis out, *taking care not to bend volume-control spindle.* (See Fig. 14.)

(7) Turn tuning control (left-hand spindle) so that moving plates of ganged condenser are fully engaged with the fixed plates (to protect them).

***Note.*—The greatest possible care should be taken of the ganged condenser.**

To examine unit turn on side so that unit rests on side nearest U10 holder. Not on coil cans.

How to Adjust the Mains Transformer for Voltage of Supply

When the mains voltage is between :—	Put either plug into the socket numbered :—	Put remaining plug into the socket numbered :—
95 and 102	4	5
103 ,, 110	4	6
111 ,, 118	3	5
119 ,, 127	3	6
128 ,, 136	2	5
137 ,, 145	2	6
146 ,, 155	1	5
156 ,, 164	1	6
190 ,, 205	4	7
206 ,, 222	3	7
223 ,, 240	2	7
241 ,, 260	1	7

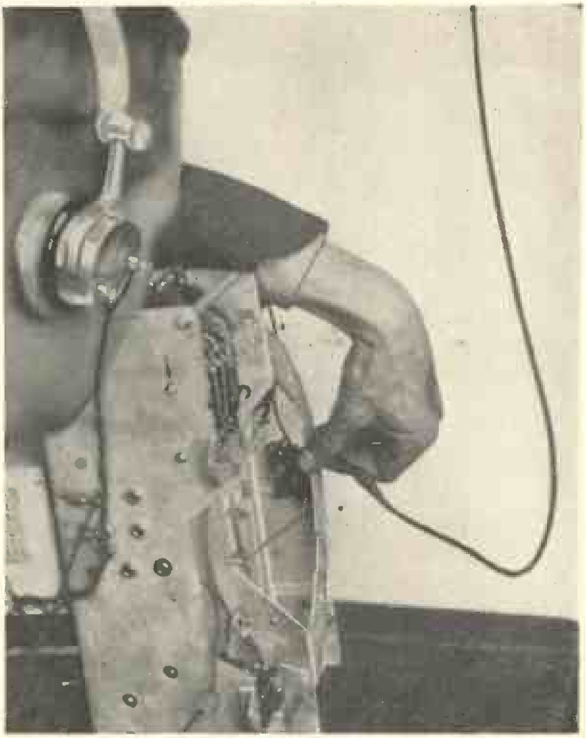


Fig. 7.—Testing for Fault on the Spindle Washers of the Aerial Trimmer Condensers.

This is done by touching the aerial on the fixed vanes.

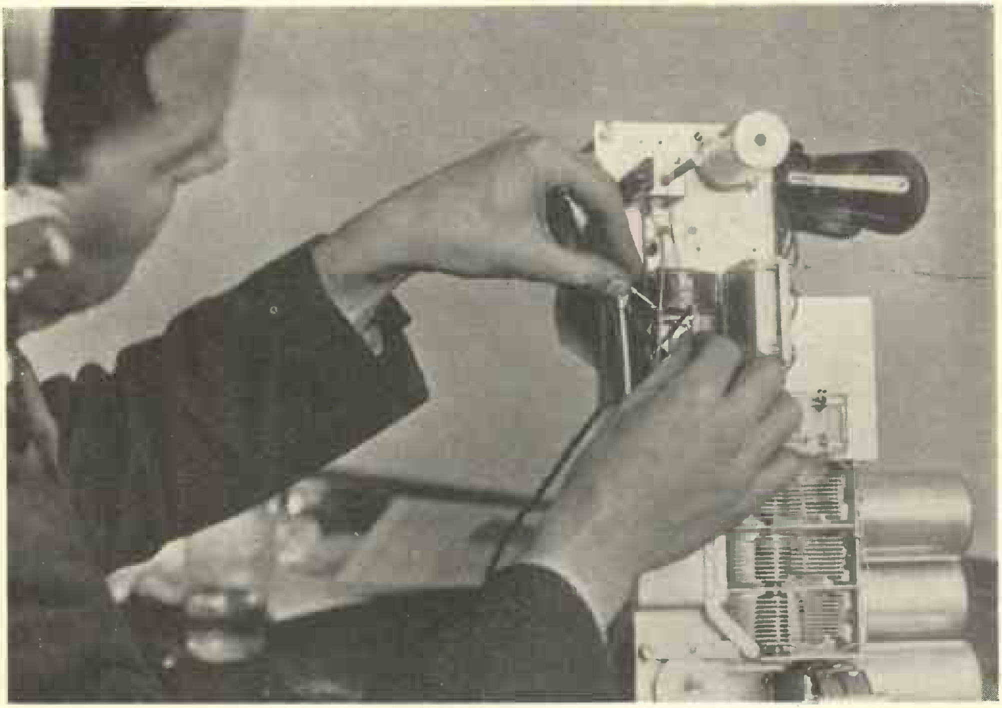


Fig. 8.—Testing for Pick-up Signals at Volume Control.

HOW TO CHECK UP THE TUNING COILS

The following is a brief description of tuning arrangements (see Fig. 2) :—

The H.F. signal is fed from the aerial *viâ* the variable aerial trimming condenser VC4 (see Figs. 2, 3 and 6) to the aerial coils of the pre H.F. band pass circuit which are wound on the same former (see Fig. 3), L1 and L2 (long-wave coil), which are tuned by VC1 of the gang condenser. These coils are inductively coupled to the grid coils of the H.F. valve, L3 and L4, which are in turn tuned by VC2 of the gang condenser (see Fig. 3).

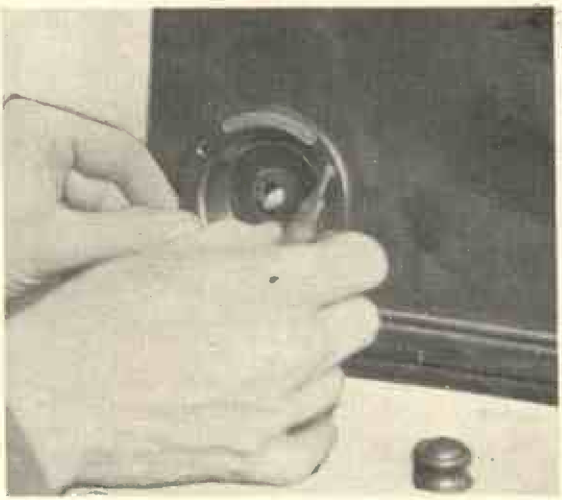


Fig. 9.—Removing Volume Control Escutcheon.

It will be noted that the moving vanes and frame of the gang condenser are at earth potential (see dotted line in Fig. 2).

After magnification by the Marconi MS4B screened-grid H.F. valve (V.1. Fig. 2) the H.F. signal is coupled into the grid coils of the detector valve by the high-frequency choke in the anode circuit of the H.F. valve—CK1 and the coupling condenser C2 (·0005 mfd.).

The grid coils of the detector valve L5 and L6, which are wound on the same former as the reaction coils, L7 and L8, are tuned by "VC3" of the gang condenser which, it should be noticed, has a small "padding" condenser, C5 (·01) in series with it to reduce the tuning range of the coil to suit the condenser and facilitate ganging.

If a failure of radio performance is found on either or both wave bands, but gramophone reproduction is satisfactory, the tuned circuits, wave change switch contacts, and H.F. valve may be tested by applying the signal from the aerial to each tuned circuit in turn, working towards the aerial from the detector valve.

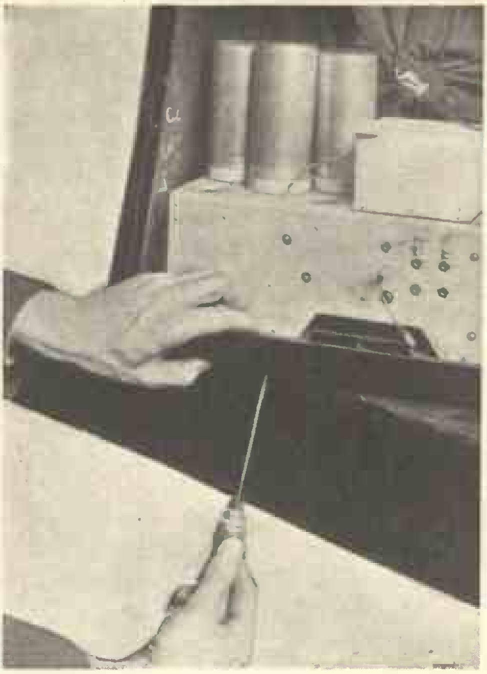


Fig. 10.—Removing the Chassis Securing Screws by Resting the Base of the Cabinet over the Edge of a Table.

How to Test Detector Grid Tuning Circuit

Set the scale to the wavelength of a local station which is known to be transmitting and touch the anode terminal of the H.F. valve (with the flex lead connected).

This will feed the signal from the aerial to the grid circuit of the detector valve through the coupling condenser "C2."

Signals should be heard, but tuning will be flat, due to the fact that only one tuned circuit is being employed.

Valve Table

(Volume Control Full on)

Readings Approximate. Valves in and alight unless stated otherwise.

Valves.	Location from Rear.	Appearance.	Temp.	Function.	Anode Current.	Avo Scale.	Anode Volts to Frame (D.C.).	Avo Scale	Screen Current D.C. m/A.	Avo Scale.	Screen to Frame Volts (D.C.).	Avo Scale.	Grid-Bias Volts.	Avo Scale.	Fil. or Heater Volts.
MS4B (V. 1)	Left	No glow	Just warm	Screened grid H.F.	1·2 m/A (between tag and top terminal of valve)	·012	150·0 (tag to frame of chassis)	1,200 V	·5 m/A (anode socket of holder to anode pin of valve) (adaptor)	·012	40·0	1,200 V	— 1 Grid to Cathode	120	4·5 A.C.
MH4 (V. 2)	Centre	No glow	Warm	Detector	2·0 m/A (signal tuned in)	·012	70·0	1,200 V	—	—	—	—	·2 Grid to Cathode	12 V	4·5 A.C.
MPT4 (V. 3)	Top Right	Slight glow	Hot	Pentode Output valve	25·0 m/A	·12	280·0	1,200 V	3·5 m/A	·012	150·0	1.200 V	1·3	12 V	4·5 A.C.
U10 (V. 4)	Bottom Right	No glow	Warm	Rectifier	16·0 m/A each anode	·12	A.C.	—	—	—	—	—	—	—	4·5 A.C.

Notes.—A. Values especially of grid bias are not necessarily "Actual," but are as indicated on Avo scale given.
B. If voltage tests are taken at sockets with valve *out*, higher readings must be expected.
C. Higher readings with valves in suggests either low-emission valves or biassing resistors "gone high." If low voltages are found with valves in suspect "shorted" biassing resistances.

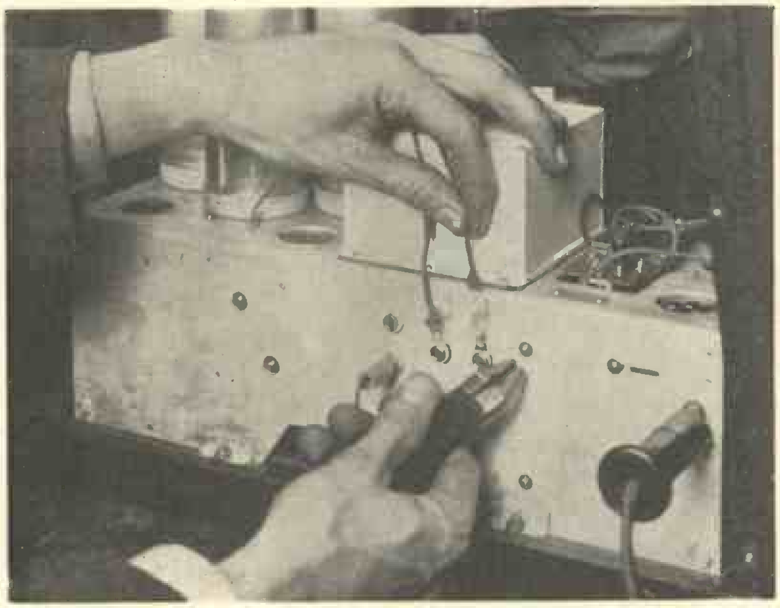


Fig. 11.—Cutting the Loud Speaker Leads close to the Tags.

If no signal is heard, suspect the following :—

(1) An earth on a tuning coil or its connections.

(2) A break in a coil or its connections.

(3) Switch contacts " h " and " g " not functioning properly. *Note,* if the station to be tuned were on the medium wave band and contacts " h " and " g " did not short circuit the long-wave coil L6 correctly, the station would not be heard.

(4) Switch contacts " f " and " e " not closing properly.

(5) A disconnection between the grid socket of the detector valve holder and the grid leak R6 or a faulty grid condenser C.17.

(6) Switch contacts " d " and " e " not closing properly, thus throwing a negative bias on the detector valve by allowing R12 (600 ohms) to function.

(7) A short circuit between the moving and fixed vanes of VC3 (see Figs. 2 and 5).

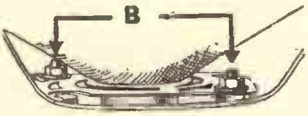


Fig. 12.—The Loud Speaker "Spider" Adjusting Screws.

How to Check Coils L5 and L6 and Switch Contacts "h" and "g"

Measure resistance between green lug of C5 (padding condenser) and frame of radio unit. With wavelength switch in " MW " position reading should be 4·5 ohms (medium wave coil L5) and with the wavelength switch in " LW " position approx. 27 ohms (L5, plus L6).

If no alteration in resistance is noticed on turning from "LW" to "MW," examine switch contacts "h" and "g" and "f" and "e."

If an open circuit is shown examine coils for break in winding or wiring and examine switch contacts " f " and " e "

If a short circuit is shown suspect a short to earth due to a wire touching the frame of the unit somewhere.

Note.—If the aerial wire is touched on to the green lug of condenser C5 signals should also be heard.

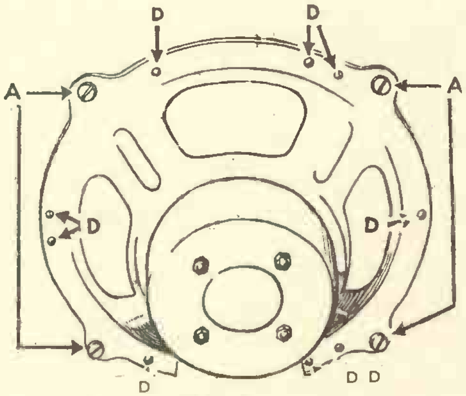


Fig. 13.—The Cone Supporting Frame of the 42 Loud Speaker.

Fig. 14.—The Right Way to Lift out the Chassis.

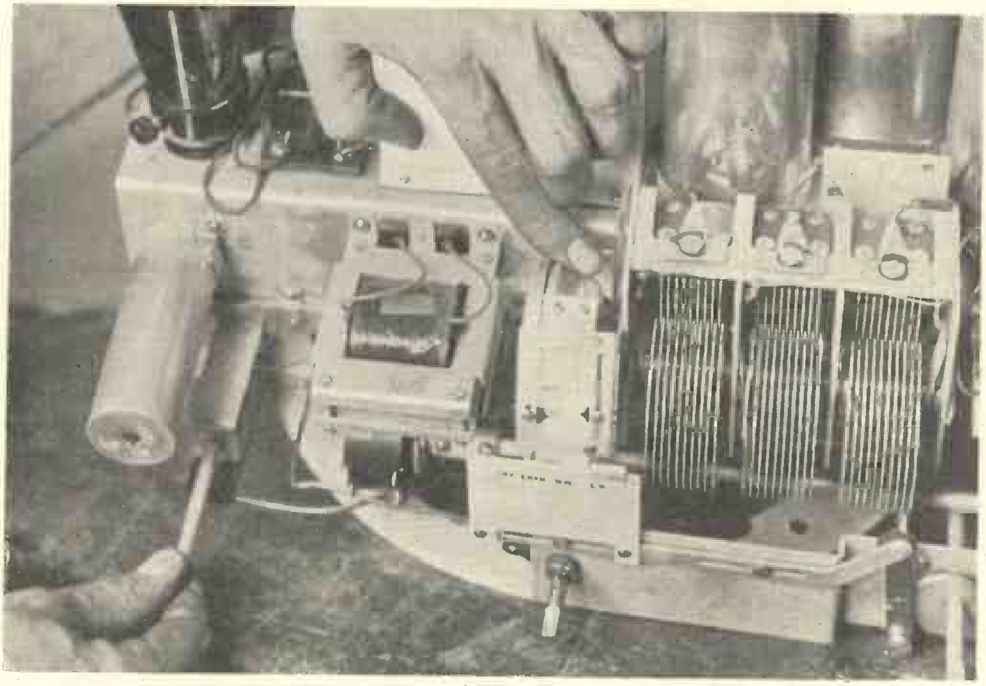


Fig. 15.—Turning the Scale to Clear the Pilot Lamp.

If signals are heard here and not when the anode terminal of the H.F. valve is touched, the fault must lie in the anode lead or the coupling condenser C2.

How to Check Up the Grid Circuit of the H.F. Valve

Attach aerial wire to trimmer lug of VC2 (fixed vanes); louder signals should be heard here if H.F. valve is functioning correctly.

If signals are not heard, check the emission of the H.F. valve and its heater for continuity. If the valve is O.K., proceed to test L3 and L4 as follows :—

Fig. 16.—Adjusting the Hum Adjuster.

Measure resistance between green lug of C1 (right-hand side of Fig. 3) and grid socket of H.F. valve holder.

The resistance with switch in MW position should be 4·5 ohms (MW coil, L3 only), and with switch in LW position approximately 27 ohms (L3 plus L4—long-wave coil).

If an open circuit is shown, check coils for a broken winding or wiring. If no change in resistance is observed on moving switch from MW to LW, check up switch contacts "a" and "b."

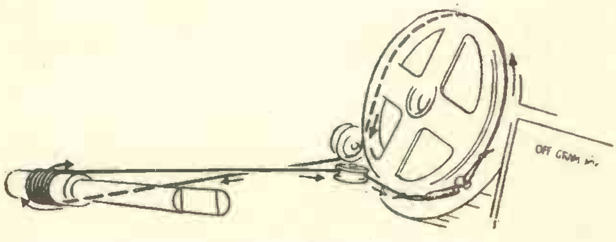


Fig. 17.—Showing how the Cord is Fitted to the Drum.

If after checking up coils no signal is heard, examine R2 (2,000 ohms, Fig. 3) for continuity and condenser C1 (·01 mfd., Fig. 3) for breakdown to earth. Also test between moving and fixed vanes of VC2.

How to Check up Aerial Coils "L1" and "L2"

Apply the aerial wire to the green lug of VC1 (fixed vanes, see Fig. 3).

If no signals are heard here check coils as follows :—

Measure resistance between green lug of C1 and green lug of VC1.

Resistance should be, with switch in MW position, 4·5 ohms, and with switch in LW position approximately 26 ohms.

If an "open" is shown, check up coils as before. If no change in resistance is shown on turning from LW to MW on switch, examine contacts "c" and "b."

How to Test the Low-Frequency Portion of the Circuit with a Pick-up

If no radio signal is available, connect up a pick-up and employ the signals from a record

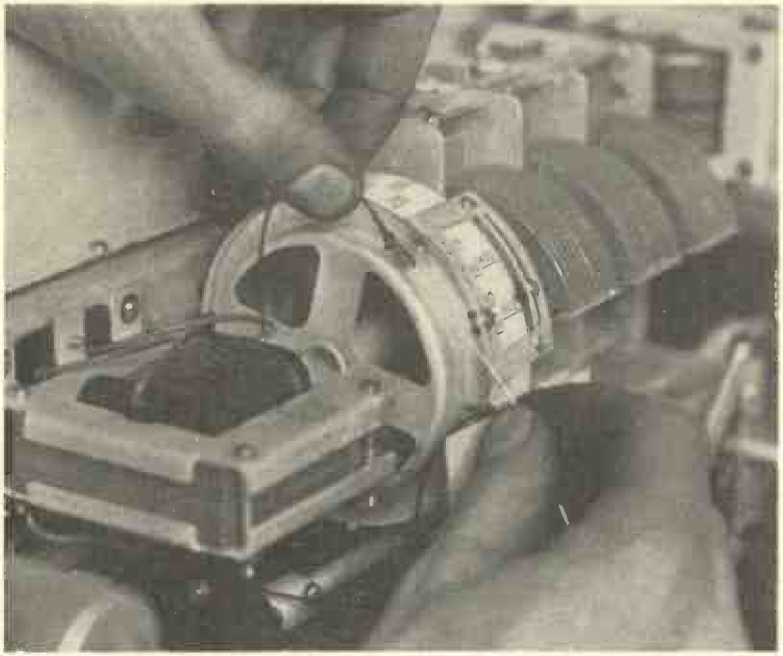


Fig. 18.—Fitting a New Cord to the Drum of the Marconiphone 42 Receiver.

Note the wire hook. (See also Fig. 17.)

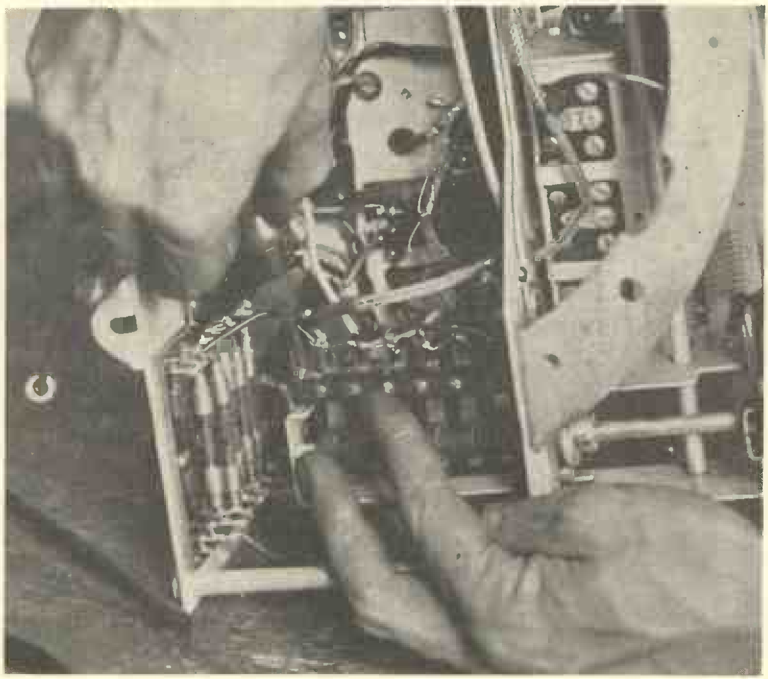


Fig. 19.—How to Remove Latest Pattern Wavechange Switch Contact Block for Adjustment.

to test the L.F. portion of the circuit.

Checking the Detector Valve

Having checked the arrival of the signal from the pick-up between the grid socket and cathode socket of the detector valve, insert a pair of headphones in the anode circuit of that valve, either with a testing adaptor, or by disconnecting a wire from CK2, and listen for signal. If no signal is heard, check up detector valve for emission, heater continuity and H.T.

Checking the Intervalve Transformer

Having cleared the detector valve, listen with phones across primary winding of intervalve transformer T1 (lugs 1 and 2). If no signal is heard, disconnect one wire to primary and check winding resistance, which should be approximately 1,000 ohms also test with phones from C11 to cathode of detector valve for signals, if necessary examining C11 (·5 mfd., lugs 5 and 6 in condenser " can "—see Fig. 3).

To check secondary winding of inter-valve transformer, listen between grid socket of pentode and frame of radio unit, if necessary checking up resistance of secondary winding of transformer (lugs 3 and 4—D.C. resistance approximately 10,000 ohms).

Checking the Output Valve

Next check up voltages and emission of pentode valve, and insert headphones in anode circuit of valve and listen for loud signals. If no signals are heard, examine primary of output transformer " T2 " (lugs 3 and 4—see Fig. 3). D.C. resistance should be approximately 1,000 ohms.

If no signals are heard across the secondary winding of T2 (D.C. resistance approximately ·5 ohms with loud speaker disconnected), check winding, finally examining loud speaker coils for short jamming on magnet poles, or disconnection in either coil or flexible leads to coil.

Reganging the Model 42

It is not advisable to attempt to re-gang the Model 42. If, however, this is attempted, set the aerial trimmer condenser to about half value and trim ganged condenser to maximum signal on a wavelength of about 250 metres. Do not forget to seal the trimmer condensers (Fig. 23) again.

Set the volume control to the minimum convenient signal strength when ganging.

THE LOUD SPEAKER

Do not attempt to dismantle the loud speaker for any purpose without carefully reading the notes—see Figs. 12 and 13.

General Fault Finding Chart for Marconiphone Model 42

Buzz or rattle.	Defective valve. Defective or dirty pick-up (if on gram only). Dust in gap of loud speaker.
Hum.	Loose laminations of mains transformer. Hum adjuster requires adjusting (Fig. 16). Sliding contact of hum adjuster not making contact (Fig. 16). No or defective earth or earth wire. Short circuit or fault to earth from tuning coils. Defective detector valve. Unscreened or defective screening of pick-up leads. Screening of pick-up leads not properly earthed. Aerial wire running too close to mains wiring or flex.
No radio, gram O.K.	Check back tuning circuits (see page 619). Check up aerial and earth. Check up emission of H.F. and detector valves. (See valve table on p. 620). Check up reaction coils.
No radio and no gram.	See that loud speaker is really O.K. by checking continuity of coils and connections to radio unit. Test output of set. Examine H.T. supply (see p. 617). Work back from loud speaker through L.F. stages, testing continuity as you go (see p. 617).
Radio O.K., gram poor or nil.	Examine switch contacts " d " and " e " (Fig. 2). Check output of pick-up with headphones. Check up contacts of volume control. Check arrival of signal from pick-up between grid socket of detector valve and cathode socket, with headphones.

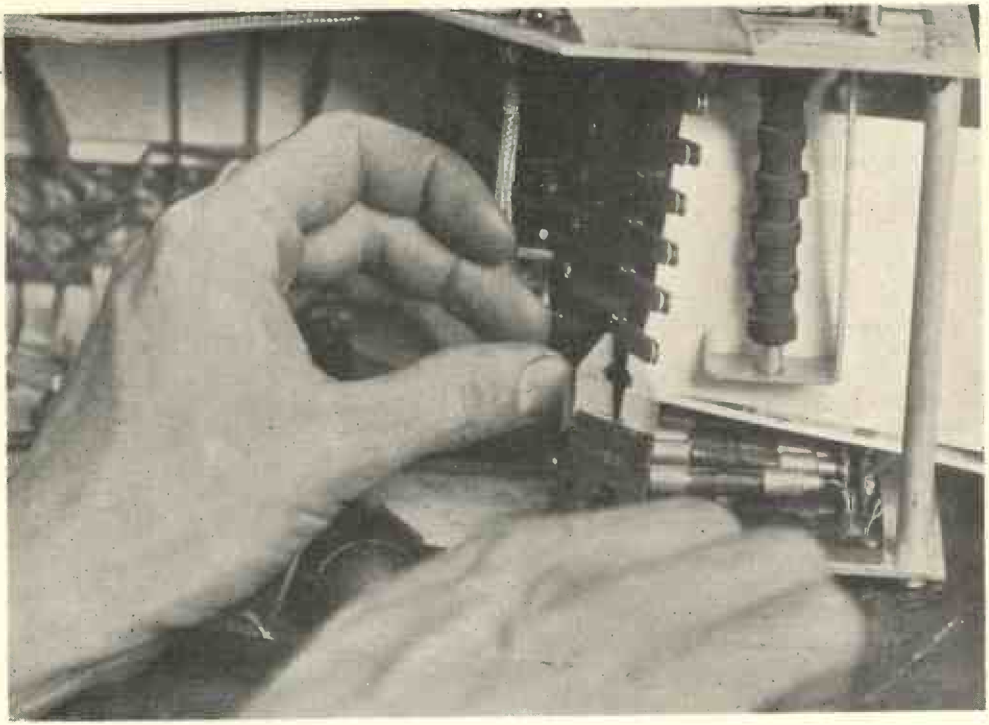


Fig. 20.—Adjusting the Contactors of the Latest Pattern Switch.

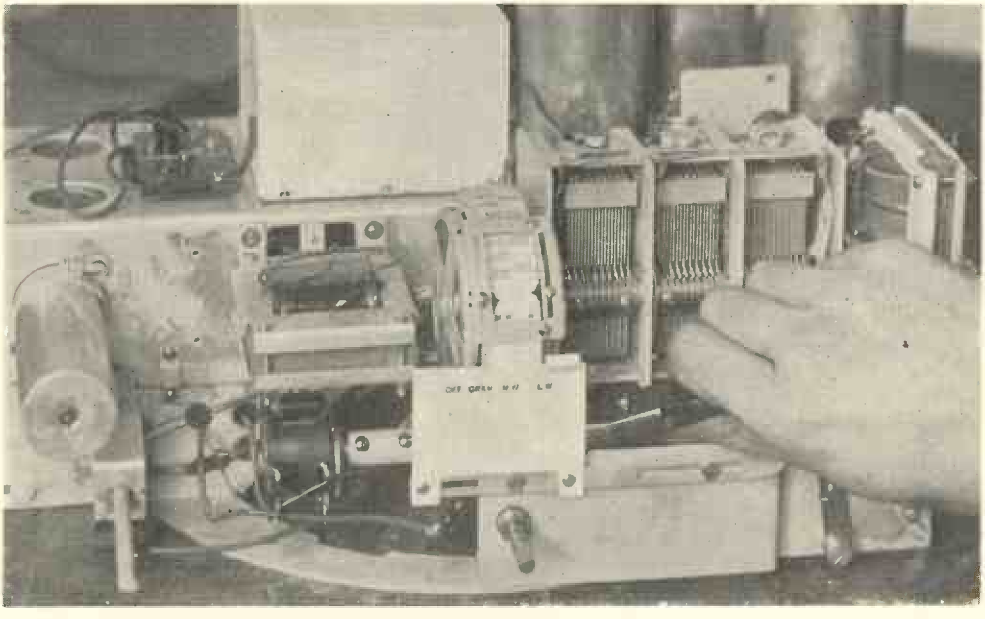


Fig. 21.—Bending Back the Wavechange Indicator Scale to Clear Escutcheon.

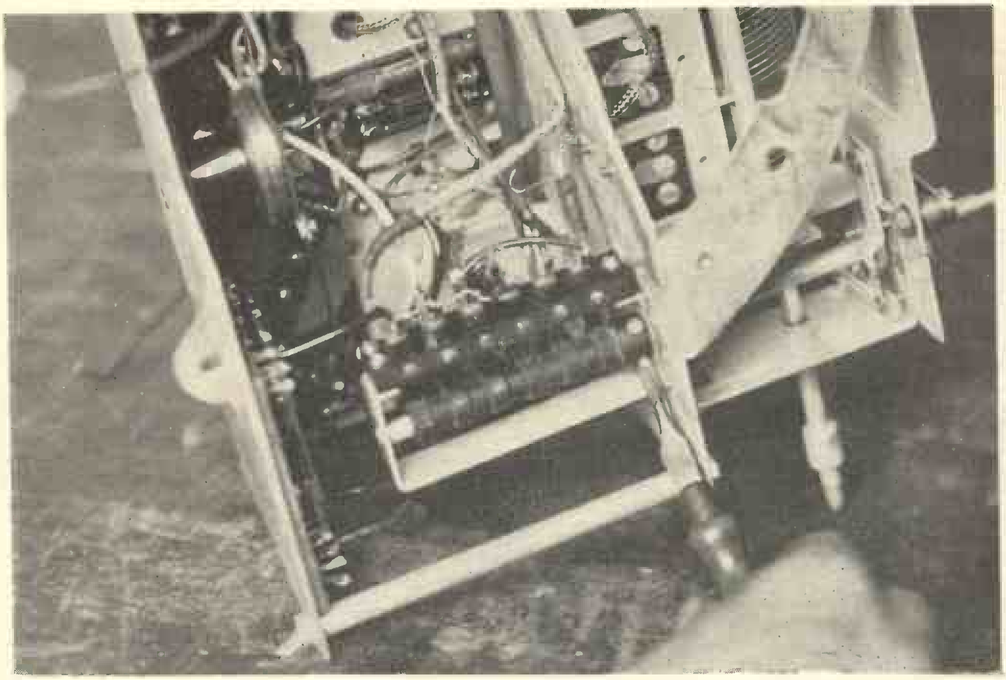


Fig. 22.—Tightening the Wavechange Switch Barrel Grub Screws.

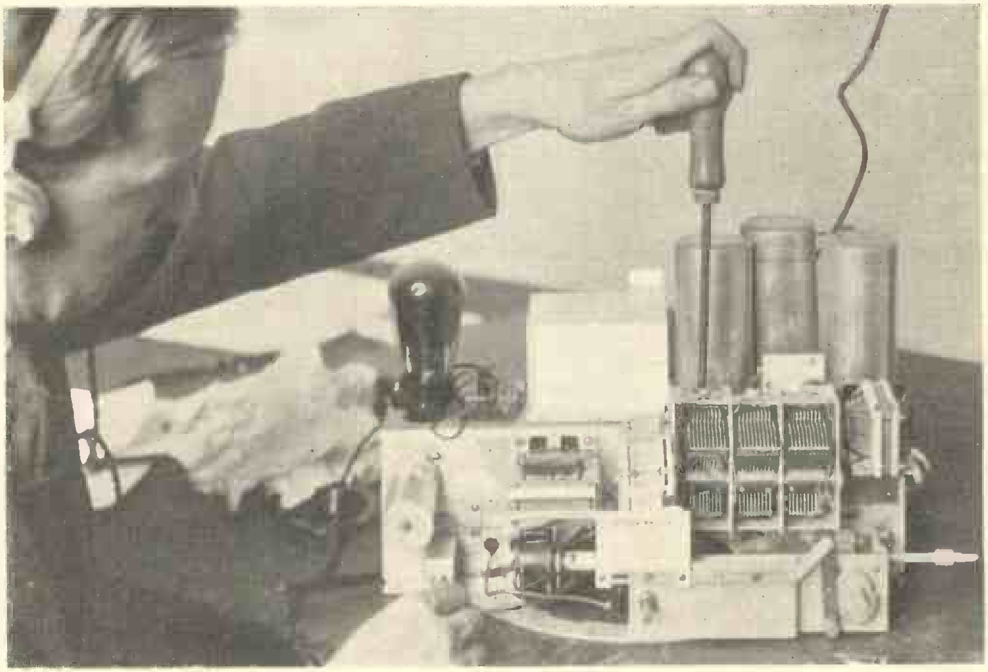


Fig. 23.—This shows how the Condensers are Ganged.

How to Dismantle the Loud Speaker

Take out the cone-securing ring screws (D in Fig. 13), and put them carefully on one side. Next remove the three sections of the cone-securing ring, together with the felt ring to which they are attached.

Do not attempt to separate the metal sections of the ring and the felt ring.

If the felt ring is left in position, reassembly will be greatly simplified.

Lifting Out the Cone

Next remove the nuts "B" (Fig. 12) which secure the cone-centring spider to the magnet, and having removed the coil leads from the radio unit, lift the coil and cone out.

When doing this take great care not to lose the spring and washers under the spider-retaining nuts.

If these are not correctly reassembled, rattle or buzz may result, and the nuts become loose.

Take care to see that the cone is put in *a safe place* when it is removed.

Warning.—In no circumstances touch the hexagonal nuts at the rear of the magnet. If these are loosened the correct location of the cone-supporting frame and magnet will be upset, and some time may be required to readjust their correct relationship.

How to Clean Out the Magnet "Gap"

Rattle or buzz may be caused by the permanent magnet picking up small particles of metal or dust. To clean out the gap do not blow or attempt to brush the dust out. Procure a small slip of plasticine and carefully wipe round the sides of the gap.

Any particles of dust will stick to the plasticine and be removed with it, instead of merely shifting their position, which is what usually happens when "blowing" is resorted to, only to work back into the "gap" in due course and cause trouble again.

How to Replace the Cone

Place the loud speaker on its back and lay the cone and coil in position so that the holes in the spider locate over the bolts on the front of the magnet unit (B, Fig. 12).

Next replace the felt ring, and with it the three sections of the cone-securing ring and insert the securing-ring screws (D, Fig. 13), screwing them up *lightly*.

Replace the nuts on the spider-retaining bolts (B, Fig. 12), *loosely*.

How to Recentre the Coil in the Magnet Gap

Looking down on the cone, centre the cone and coil up carefully, then tighten the securing-ring screws (D, Fig. 13).

Having secured the edge of the cone, move the coil about with the forefinger and thumb of each hand until the coil is central.

Now connect up the loud speaker to the radio unit again, and tune in some loud signals, moving the coil this way and that until rattle stops, then screw up the spider-retaining nuts (B, Fig. 12).

Special Note.—Make sure that it is the loud speaker which is at fault, and not the radio unit, by testing with a speaker which is known to be O.K.

THE TREND OF DEVELOPMENT IN AMERICAN RADIO RECEPTION

By W. R. G. BAKER, VICE-PRESIDENT OF THE RCA VICTOR COMPANY INC.

IN surveying the development of radio reception in the United States, it may be well to describe briefly the growth and present status of American broadcasting so that the reader may obtain an appreciation of the problems which confront the manufacturer of radio apparatus in this country. Private ownership of broadcasting stations, the large area to be served by these stations, output powers and wavelength allocations of transmitters, and changing economic conditions, are all factors which have influenced, to a considerable extent, the technical development of receivers.

Fig. 1.—RCA VICTOR MODEL R.78 TWELVE-VALVE SUPERHETERODYNE RECEIVER.

Note the acoustic chambers on both sides of the chassis.

How Listeners are catered for

Broadcasting in the United States may be said to have begun twelve years ago, when listeners heard the presidential election returns from the experimental transmitter (now station KDKA) of the Westinghouse Electric and Manufacturing Company at East Pittsburgh, Pennsylvania. Soon afterwards other stations came into existence, and the number grew rapidly as the public acclaimed this new, fascinating form of entertainment. At the present time there are 602 licensed broadcasting stations in the United States (exclusive of possessions) serving approximately 17,000,000 homes scattered over an area of slightly more than 3,000,000 square miles.

The Three Transcontinental Networks

There are three transcontinental networks, two of them being operated by the National Broadcasting Company, and the third by the Columbia Broadcasting System. These chains comprise a total of less than 200 stations leased, mainly, on a part-time basis, and the remainder are independently owned and operated. The broadcasters obtain their revenue through the sale of time to advertisers, and thus the listener is allowed to enjoy the wide variety of entertainment offered without the burden of a direct tax on his receiving instrument.

How Minimum of Interference is obtained

Regulation of broadcasting stations and the granting of licences are in the hands of the Federal Radio Commission, which was created by the Radio Act of 1927. This body, shortly after its formation, established the present wavelength allocations and power limits. That part of the frequency spectrum between 550 and 1,500 kilocycles was reserved for broadcasting and divided into bands of 10 kilocycles each. Certain of the larger stations were given cleared channels and the others were grouped, with respect to location and time of operation, on the remaining wavelengths, so that a minimum of interference would result. The maximum power was set at 50 kilowatts.

Evolution of Receivers

The first receivers used for broadcast reception were nearly all of the crystal type and utilised headphones. But, before long, there were placed on the market reliable valves which gave improved detection and make possible the regenerative receiver. This receiver became very popular because it was much more sensitive than its predecessors, and it tended to promote keen competition among listeners for long-distance reception.

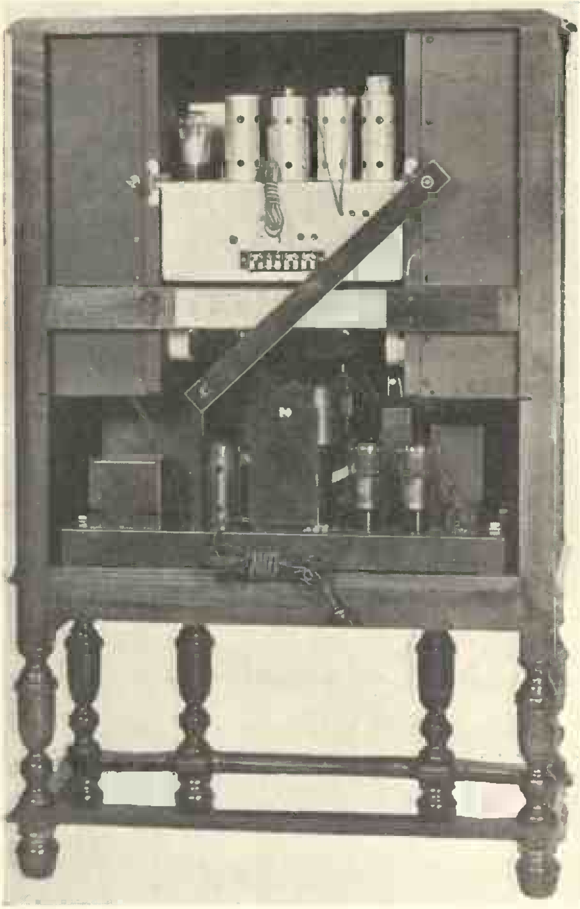


Fig. 2.—Back View of RCA Victor Model R.78.

The Tuned Radio - Frequency Receiver

The regenerative receiver did not give very good fidelity of reproduction and had the disadvantage of re-radiating into the aerial system and thereby interfering with other receivers. It gave way to the tuned radio-frequency type of receiver, utilising, normally, from one to three stages of radio-frequency amplification, a detector, and one or two stages of audio amplification. Later, the introduction of neutralisation in the radio-frequency stages provided greater selectivity and better quality of reproduction, together with improved stability and freedom from oscillation.

Development of the Moving-Coil Loud Speaker

The next important step in broadcast reception was the development of the moving-coil loud speaker, which improved greatly the quality of reproduction. At about this time the magnetic pickup appeared, and the gramophone was combined with the radio receiver, the audio amplifier and loud speaker being common to both. About this time, too, the table model receiver was superseded by the console. The large cabinet provided the necessary baffle area to

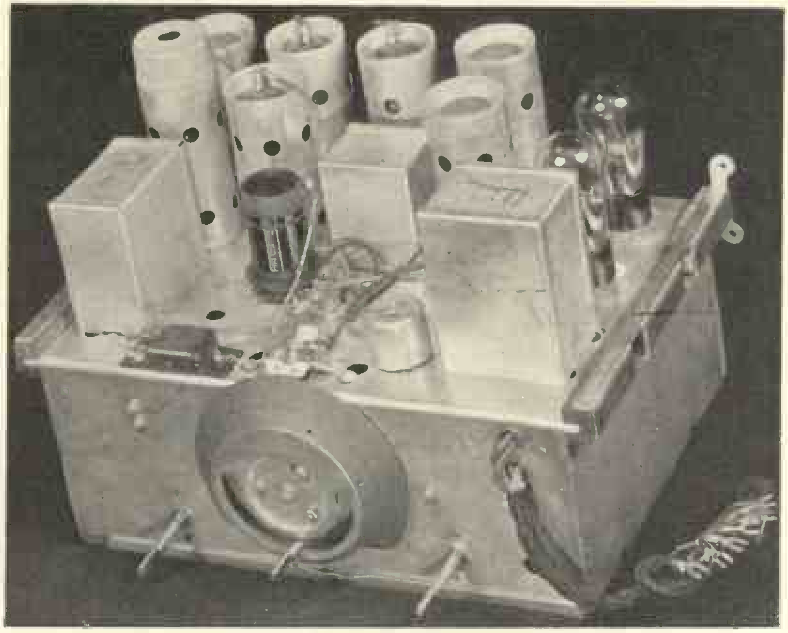


Fig. 3.—CHASSIS OF RCA VICTOR MODEL R.78.

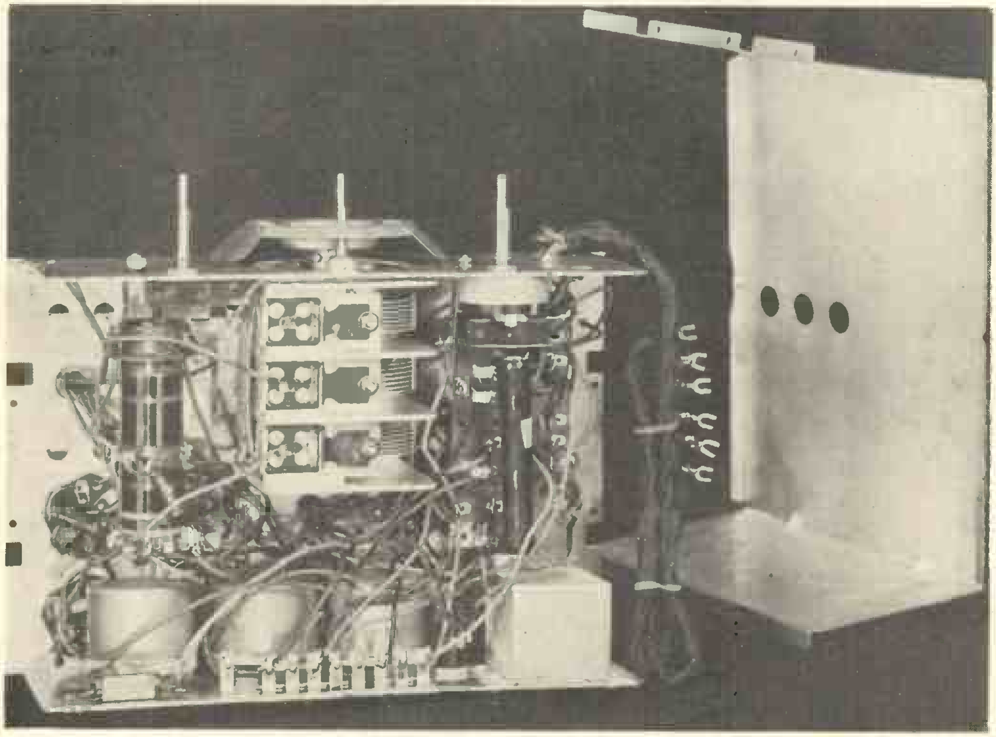


Fig. 4.—BOTTOM VIEW OF RCA VICTOR MODEL R.78 CHASSIS.

Fig. 5.—Power Unit and Audio Amplifier of RCA Victor Model R.78.

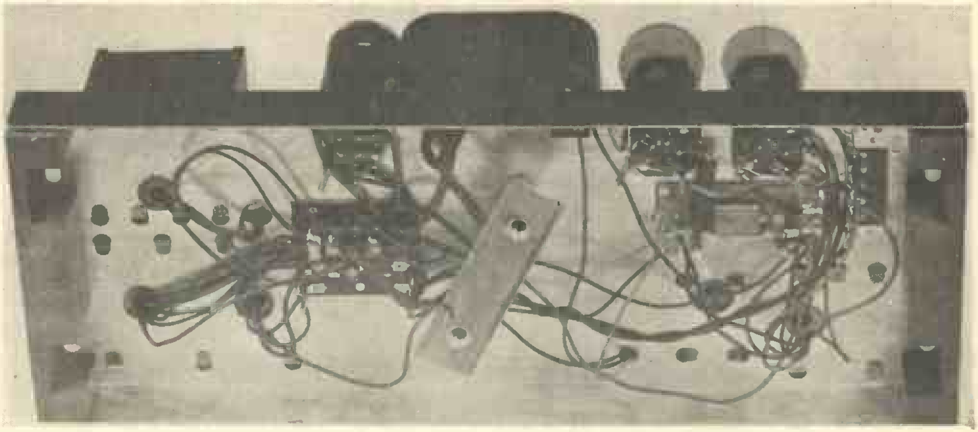


Fig. 6.—Bottom View of Power Unit and Audio Amplifier.

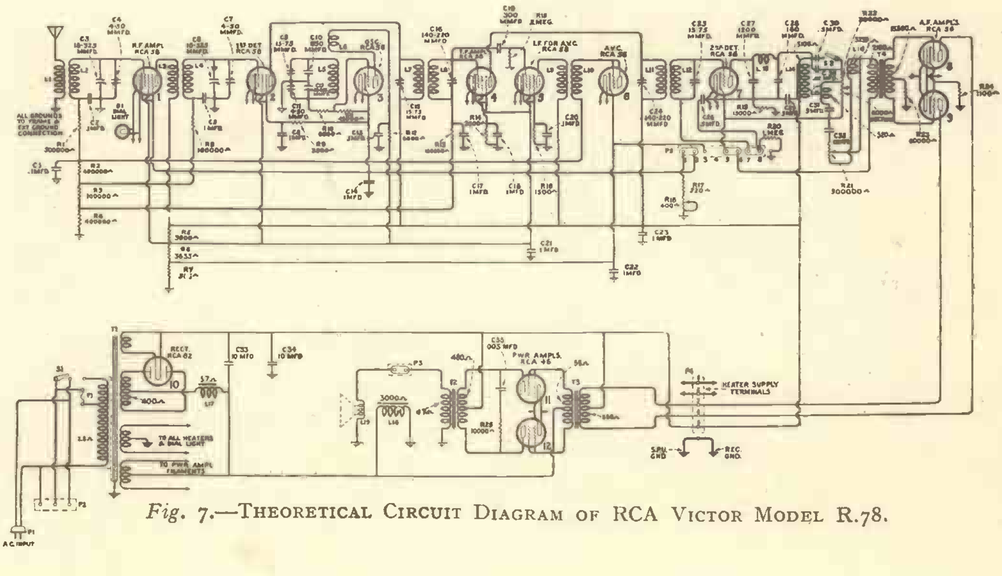


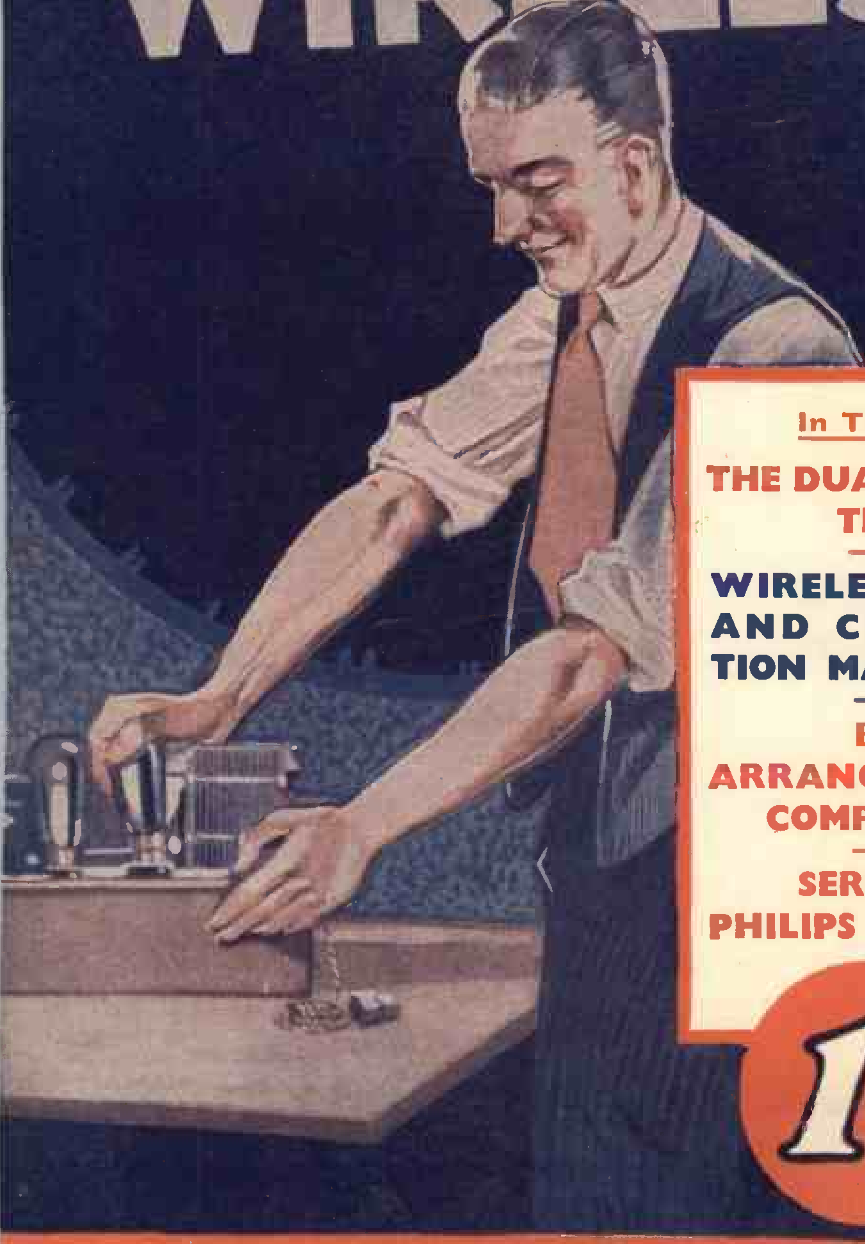
Fig. 7.—Theoretical Circuit Diagram of RCA Victor Model R.78.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

58+

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS



In This Part

THE DUAL PURPOSE THREE

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

BEST ARRANGEMENT OF COMPONENTS

SERVICING PHILIPS RECEIVERS

1/-

Part 14

IN ABOUT 24 WEEKLY PARTS

bring out the improved quality of the moving-coil loud speaker, and, at the same time, satisfied the wants of the consumer, who had come to regard the receiver not only as a musical instrument but also as a piece of furniture which must fit in with its surroundings in the home.

The Alternating-Current Receiver

The alternating-current receiver was the next important step. It was well received because its cost of operation and the attention it required were considerably less than for the multi-valve battery receiver.

Effect of Screen-Grid Valve

The development of the screen-grid valve, which practically eliminated the necessity for neutralisation, made possible receivers which gave still better fidelity of reproduction, amplification, selectivity and stability.

Fig. 8.—RCA VICTOR MODEL R.43.
This is an eight-valve battery-operated superheterodyne receiver.

Development of the Superheterodyne Circuit

Despite the large number of broadcasting stations in the United States, many listeners, especially in the middle western and far western regions, are situated a considerable distance from a network transmitter or from any one of the smaller independent stations. This fact has resulted in a demand for receivers with a much higher sensitivity than is considered necessary in Great Britain or on the Continent. Also, the narrow wavelength bands have made it essential that the receiver be selective enough to separate the desired station from those on the adjacent bands. The superheterodyne circuit has been found most satisfactory in meeting these requirements and, at the present time, the majority of receivers manufactured are of this type.

Effect of Economic Depression on Cabinet Design

In the autumn of 1930 there was a departure from the console receiver to the "midget" or mantel type. There are several reasons for the popularity it has enjoyed. In the first place, the average consumer felt that this small receiver would give him reasonably good reception, and although the tone quality was not as good as that of the larger set the difference in price compensated for this deficiency. By this time the economic depression had made itself felt quite generally and purchasing power was declining.

In the second place, the midget receiver requires a very small amount of space and therefore appeals strongly to people living in small houses and appartments where space is limited. A third reason may be attributed to the fact that it is easily portable and may be moved conveniently from room to room, or may be carried in the family automobile to the summer cottage.

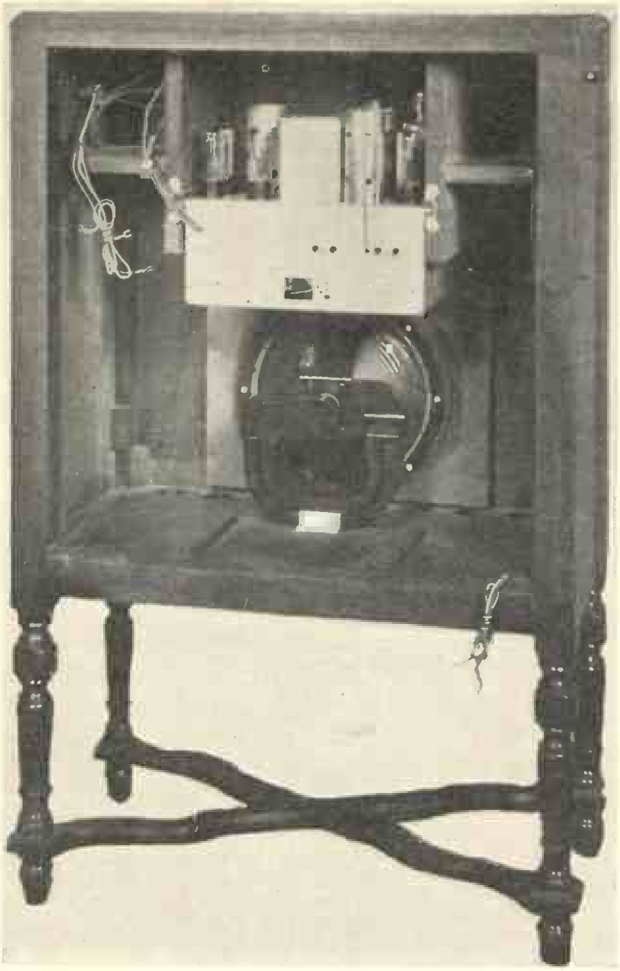


Fig. 9.—BACK VIEW OF RCA VICTOR MODEL R.43.
Showing permanent magnet loud speaker and compartments for batteries.

Development of Battery-operated Superheterodynes

In the rapid development of the alternating-current receiver there was a tendency to neglect the battery-operated receiver. Lately, however, American radio manufacturers have given more attention to this type of set in order to find a market for it in the homes in the United States not supplied with electric power. The introduction of new valves having very low filament power consumption, the application of the Class B type output amplifier, the use of the permanent-magnet moving-coil loud speaker, and improvements in batteries have made possible a superheterodyne receiver that compares favourably in performance and operating cost with the corresponding

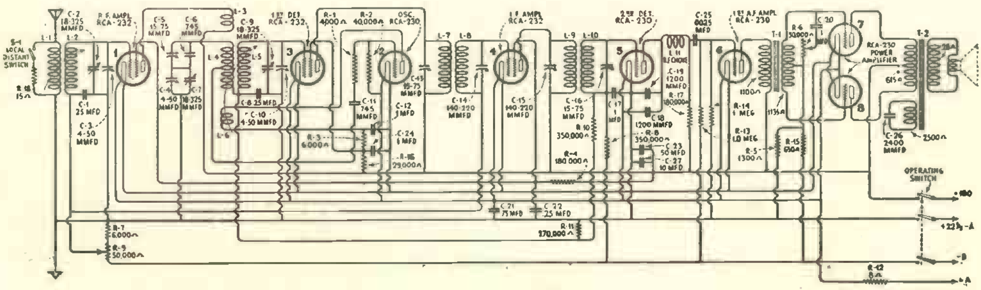


Fig. 10.—THEORETICAL CIRCUIT DIAGRAM OF RCA VICTOR MODEL R.43.

alternating-current set.

Wireless Sets in Motor Cars

Automobile radio receivers made their appearance in the United States about three years ago and have gained in popularity since that time. At present several automobile manufacturers are equipping certain of their models for radio reception. The superheterodyne circuit and the permanent-magnet dynamic loud speaker have been incorporated in this type of receiver, enabling the occupants of the motor car to enjoy a good quality of reception.

Fig. 11.—RCA VICTOR MODEL R.A.E.59.

This is a combination radio-gramophone equipped for home recording.

Sets equipped for Short-Wave and Broadcast-Wave Transmissions

The popularity of short-wave national and international reception in this country had brought with it a demand for broadcast receivers equipped to receive these waves. A considerable number of adaptors and converters have been sold which are used in conjunction with all or a part of the ordinary broadcast set, but more recently the trend has been toward the complete "all-wave" receiver capable of receiving either the short-wave or broadcast-wave transmissions through the mere turning of a switch. A number of the larger broadcasting stations in the United States operate short-wave transmitters regularly in conjunction with their main transmitters.

PRESENT TREND IN RECEIVER DESIGN

The performance of a radio broadcast receiver is ordinarily judged on the following characteristics:—

(1) Sensitivity.
(2) Selectivity.
(3) Fidelity.
(4) Power output.

Practical Limit of Sensitivity already reached

With the development of the present-day superheterodyne the radio engineer apparently has reached the practical limit of sensitivity in the radio receiver. Whereas the old style regenerative receiver gave a voltage amplification of the order of 20,000 times, the amplification of the superheterodyne is about four million times. A sensitivity of 10 microvolts per meter is easily obtained; to reach beyond this point offers little advantage because of the large amount of static incurred.

Selectivity

In the matter of selectivity the superheterodyne is likewise greatly superior to the earlier types of receivers, and in this case, also, present designs have reached the limits without sacrifice of tone quality through attenuation of the carrier side bands. The point has been reached where the transmitters are now the limiting factor with regard to interference; one might say that the receivers are more selective than the transmitters. Interference from neighbouring broadcast channels, as observed at a receiver, is due usually to cross-talk or to heterodyne beats. Cross-talk, caused by a strong adjacent channel frequency effectively passing through the receiver, is governed by the radio-frequency selectivity of the receiver and the signal-field strengths.

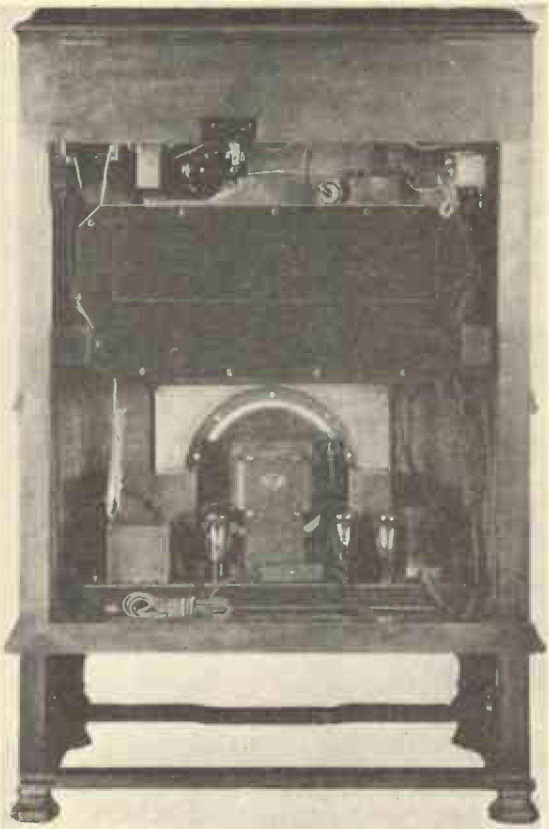


Fig. 12.—Back View of RCA Victor Model R.A.E.59

Interference Troubles

The more common form of interference which troubles the American listener is in the form of heterodyne beats, caused by high-frequency side bands and carrier

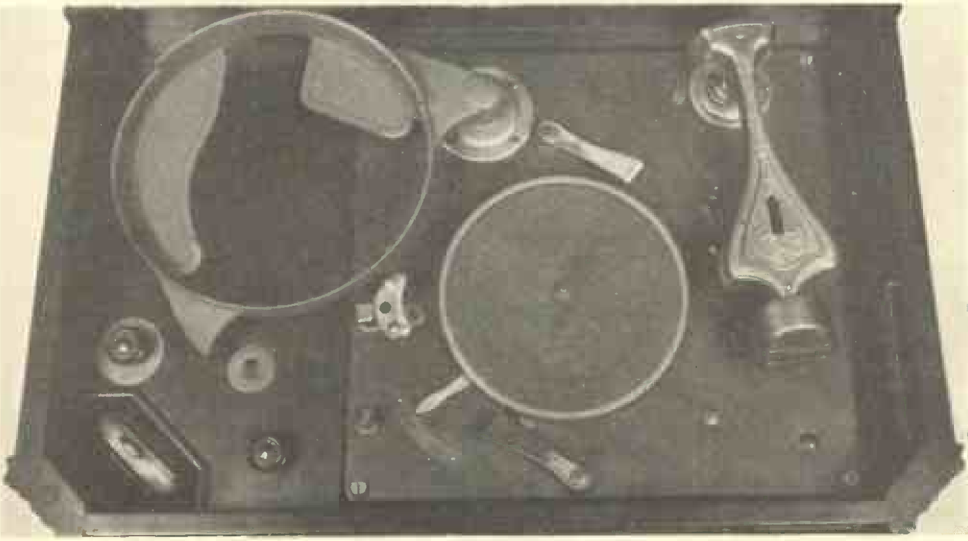


Fig. 13.—Top View of RCA Victor Model R.A.E.59.
Showing two-speed turntable, record changer, and recording microphone.

frequencies from neighbouring channels beating with the carrier frequency of the desired station. The degree of interference from this source depends on the radio-frequency and audio-frequency selectivity in the receiver and on the field strength of the transmitted carrier and side-band frequencies. Although the transmitter is assigned to a 10-kilocycle channel, such factors in the transmission system as parasitic oscillations, over 100 per cent. modulation, excessive audio-frequency range, and non-linear circuits produce side bands which spread out beyond the legitimate frequency channel and into the adjacent channels. This causes interference which the receiver cannot avoid.

Fig. 14.—RCA Victor Model R.74.
A ten-valve superheterodyne receiver.

How Fidelity has been improved

The improvement in the fidelity of radio receivers has received much attention from engineers during the past four or five years. As mentioned previously, the development of the moving-coil loud speaker marked perhaps the greatest step in this direction. The application of the push-pull audio amplifier also contributed to better quality through the elimination of the even harmonics. The frequency-fidelity characteristic of the old regenerative receiver dropped off very rapidly below 100 cycles and above 2,000 cycles, while the present-day receiver gives a nearly uniform response from 30 to 5,000 cycles. A few broadcasting transmitters in the United States have nearly flat modulation frequency characteristics from 30 to 8,000 cycles, and it is probable that these represent the practical limits for receivers with the present wavelength allocations.

Outputs up to 10 Watts now obtainable

The power output has been increased from a fraction of a watt, in the early receivers, to more than 10 watts in some of the present-day sets which use the Class B type output amplifier. This increase in power has made possible greater volume from the loud speaker and improved fidelity.

TECHNICAL FEATURES IN NEW RECEIVERS

A few of the features incorporated in present American broadcast receivers will be described briefly.

Power Detection

Most modern sets utilise what is known as "power detection," employing a triode feeding directly into the output stage without an intervening stage of audio amplification. The valve is used as a negatively-biassed detector with a plate voltage of 200 or 250 volts and a corresponding high bias. This form of detector tends to reduce distortion and microphonic feed backs, and is capable of handling comparatively large input voltages.

Tone Control

Since 1930 the majority of broadcast receivers have been equipped with tone control which, in most cases, is nothing more than a manual attenuator for reducing the higher audio frequencies and thereby increasing the relative intensity of the bass notes.

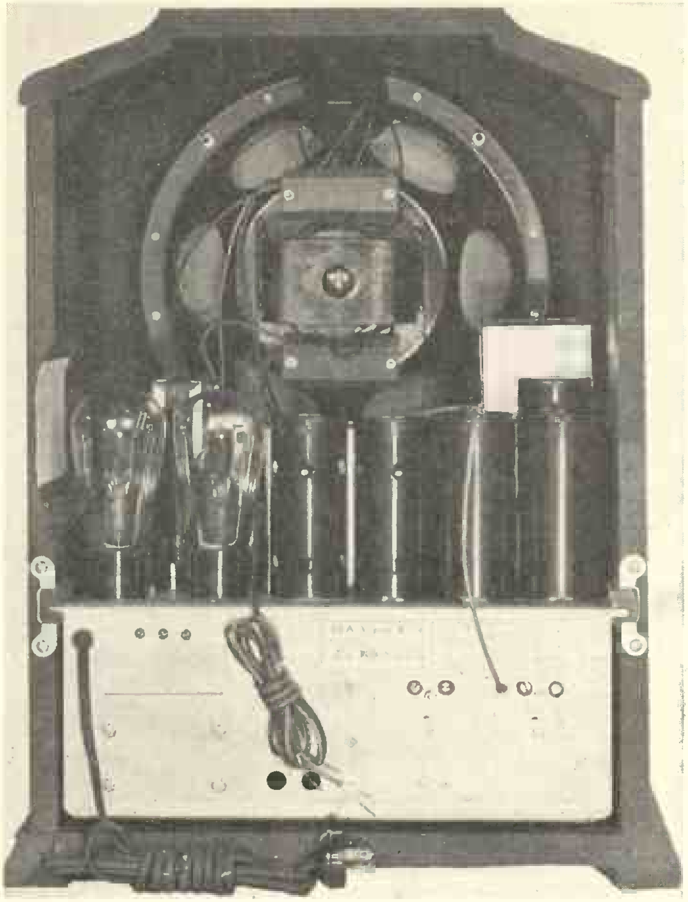


Fig. 15.—BACK VIEW OF RCA VICTOR MODEL R.74.

Automatic Volume Control

Another feature of nearly all but the very low-priced present-day receivers is automatic volume control, or, more properly, automatic gain control, which tends to maintain constant audio output irrespective of the signal input. This is, of course, an advantage in tuning from one station to another where there exists a considerable difference in the field strengths of the stations. It also compensates, to a certain extent, for some of the effects of fading. In the usual arrangement the direct-current component of the rectified output of a detector is used as additional control grid bias on the radio-frequency amplifier valves. Circuits have been developed which provide for suppression of the background noise which otherwise would be obtained between stations in tuning the receiver.

Audio-Frequency Compensation

A few of the higher quality receivers employ audio-frequency compensation, designed to correct for a certain natural characteristic of the human ear which exhibits itself in a more rapid decrease in audibility of the high and low frequencies than of the middle range of frequencies, as the volume is decreased. With this compensation the sound has the same apparent quality at all volume levels.

Obtaining High Output with Low-Power Consumption

The Class B type output amplifier has been used with marked success in some of the recent receivers. In this system of amplification the valves normally are biassed practically to the point of plate current cut-off, so that, with no signal impressed, the plate current is very small. As the grid-signal voltage swings negative there is very little reduction in plate current possible, so the effect is practically nil. However, as the grid-signal voltage swings positive there is a large increase in plate current, and by utilising two valves, each valve responds to alternate halves of the impressed waves. Because the grid and plate circuits are designed to have a relatively low impedance for each positive-voltage swing, and because the direct - current component of the plate current is very small, this method of operation permits of a high audio output with a relatively low power consumption.

The Class B type of amplifier was first used in battery-operated receivers in which the power consumption is an important factor, and because independent sources of bias voltage and plate voltage could easily be obtained. It appeared difficult to use this system in an alternating-current-operated receiver because self-bias, as usually defined, cannot be used to reduce the plate current essentially to cut-off. To

Fig. 16.—RCA Victor Model R.5.
A four-valve tuned radio-frequency receiver.

Fig. 17.—Back View of RCA Victor Model R.5.

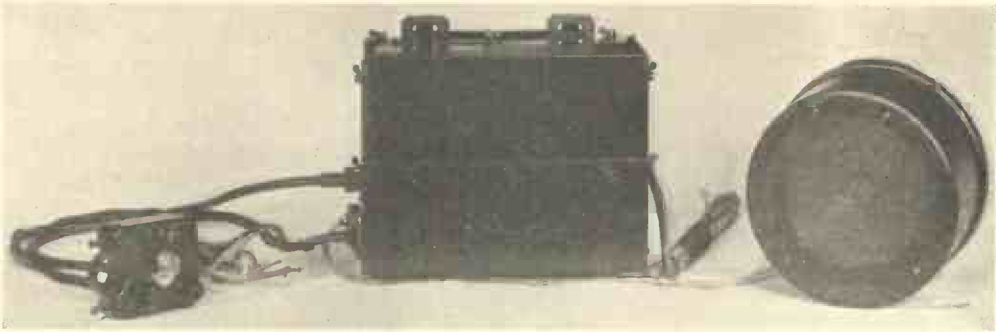


Fig. 18.—RCA Victor Model M.30.
A nine-valve superheterodyne automobile receiver, with tuning control unit.

Fig. 19.—RCA Victor Model M.30, with Cover Removed.

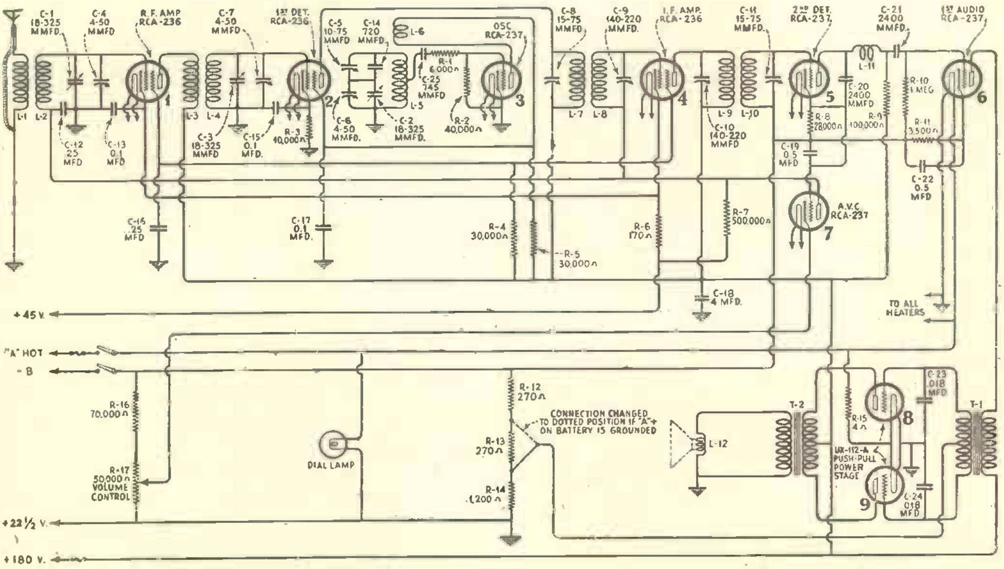


Fig. 20.—Theoretical Circuit Diagram of RCA Victor Model M.30.

overcome this difficulty special valves have been developed in which dual grids are connected together and provide, in effect, the necessary bias for this type of amplifier. This method of operating the valves makes possible a high undistorted audio output and therefore improved fidelity.

Receivers equipped for Home Recording

A considerable portion of present American receivers are combined with gramophones having two-speed turntables to allow the playing of both 78 r.p.m. and 33⅓ r.p.m. records, and also automatic record changing mechanisms. Some are equipped for home recording on composition discs of the output of the radio receiver or of the associated microphone.

Other features which have been incorporated in the radio receiver are remote control tuning, tuning indicators, twin and triple loud speakers, and electric clocks.

Fig. 21.—RCA Victor Model R.O.23.
A standard wave and short-wave receiver.

MECHANICAL DESIGN

In order to reduce the manufacturing cost of the radio receiver as much as possible the mechanical designs have been simplified greatly, and the whole assembly has been reduced in size. The reduction in size has been accomplished through the use of new small-size valves, electrolytic condensers, and improved designs of transformers, sockets, variable condensers, and other parts. The chassis base itself is fabricated from sheet steel and the component parts are riveted or bolted to this base. Sheet metal "cans" are used to shield the valves and some of the coils. Lugs or wire leads are brought out underneath the base for soldering. Figs. 3 and 4 show a typical chassis construction. To reduce vibration, rubber cushions are used for mounting the chassis in the cabinet.

In some of the larger receivers the radio-frequency section and the audio-frequency section of the receiver are constructed as separate units. The power supply, audio output, and loud speaker are assembled as shown in Figs. 5 and 6.

TYPICAL RECEIVERS

A.C.-Operated Console

Fig. 1 shows a recent medium-priced console receiver as marketed prior to

September, 1932. The rear view (Fig. 2) shows the mounting of the chassis unit and the socket power unit as well as the acoustic chambers, on each side of the chassis, which are designed to eliminate the booming produced by cabinet resonance. These chambers are tuned by means of the metal orifices at the bottom. Two views of the chassis are shown in Figs. 3 and 4, while Figs. 5 and 6 show similar views of the socket power unit.

Details of the Circuit

The theoretical diagram of this receiver is shown in Fig. 7, and the reader will recognise it as a superheterodyne circuit. The radio-frequency valve is coupled by means of transformers to the aerial and to the first detector. The secondary of each transformer is tuned by an individual section of a three-section tuning condenser, the third section being used to tune the grid circuit of the oscillator valve.

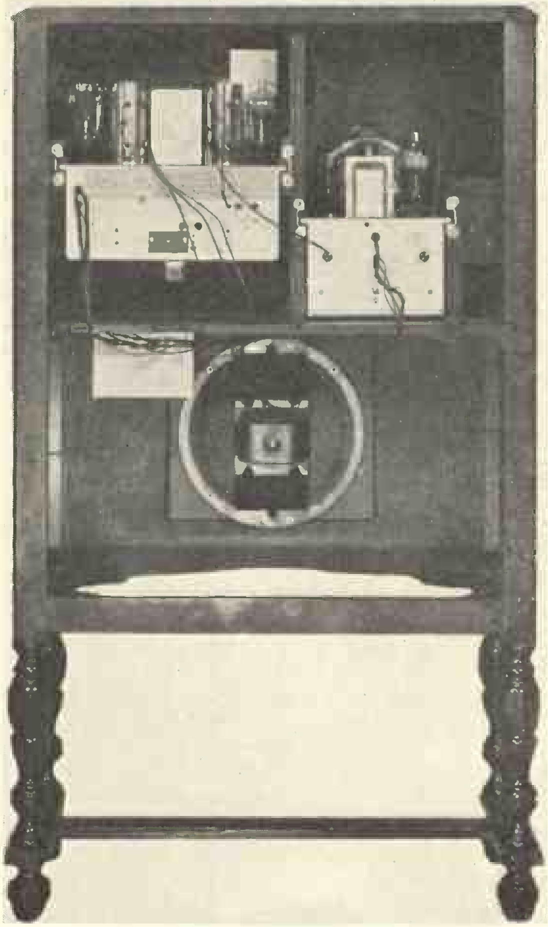


Fig. 22. — BACK VIEW OF RCA VICTOR MODEL R.O.23.

Showing arrangement of receiver chassis and converter units.

The Oscillator Circuit

The oscillator circuit is so adjusted that the generated voltage is of a frequency 175 kilocycles greater than that to which the radio-frequency amplifier is tuned. The 175-kilocycle beat frequency is fed into two valves, one being coupled in the usual manner to the second detector and the other being coupled to the automatic volume control valve. The plate current of the last-named valve flows through the resistances which provide the negative bias on the control grids of the radio-frequency valve, the first detector valve, and the intermediate-frequency amplifier valve, thereby controlling the amplification of these stages. Such a system eliminates the danger of overloading the second detector valve and makes it possible to insert the manual volume control in the audio-frequency system.

The Audio-Compensation System

The audio-compensation system and the tone control are connected with the transformer coupling the second detector to a push-pull amplifier stage which, in turn, drives the Class B output amplifier. The maximum undistorted output of this receiver is about 10 watts. In order to obtain the regulation requirements which the Class B amplifier imposes, a mercury vapour rectifier tube is used in conjunction with a low-impedance filter system. Terminals are provided for connection to a gramophone pick-up.

Battery-operated Receiver

Fig. 8 shows a superheterodyne receiver which utilises batteries as a power supply.

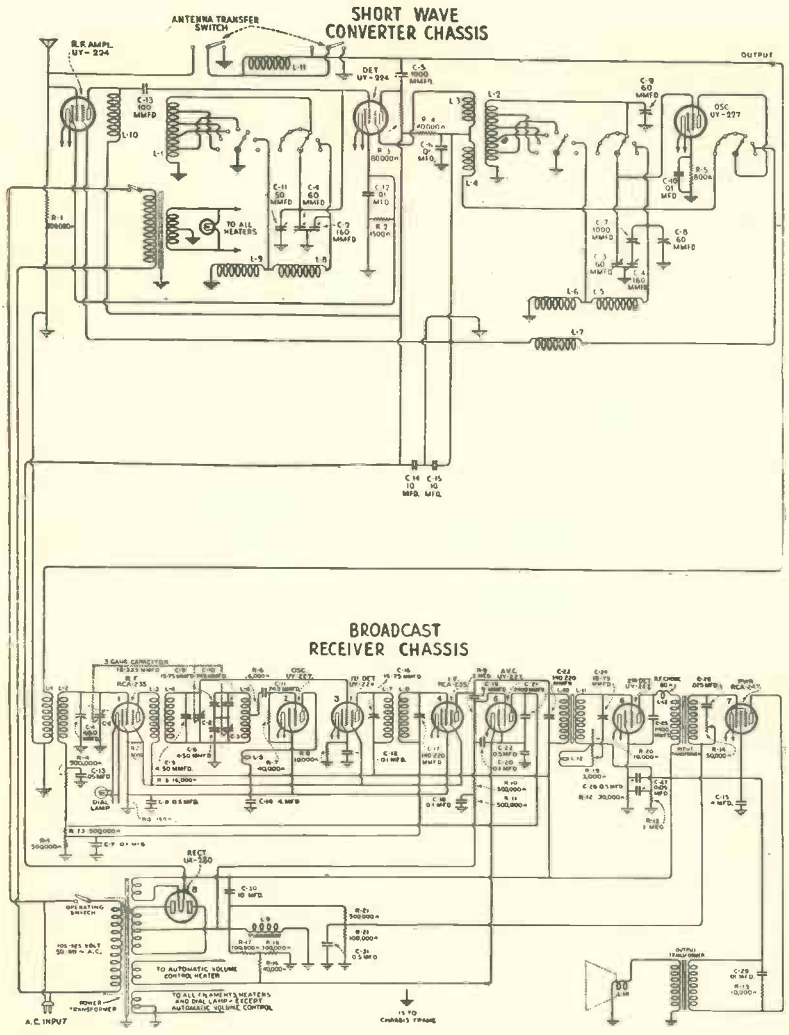


Fig. 23.—Theoretical Circuit Diagram of RCA Victor Model R.O.23.

The rear view in Fig. 9 shows the chassis, the battery compartments, and the permanent-magnet moving-coil loud speaker. The theoretical diagram is shown in Fig. 10. The use of valves requiring a very small filament current, a Class B type output amplifier with relatively low plate current requirements, and a loud speaker which requires no current for field excitation, makes this a very efficient receiver from the standpoint of power consumption.

Radio-Gramophone Combination

The receiver shown in Fig. 11 is also of the superheterodyne type, and is combined with a gramophone having a two-speed turntable and automatic record-changing mechanism. Provision is also made for disc recording. The rear view in Fig. 12 shows the arrangement of the various units. The receiver chassis is completely enclosed in a metal container. Fig. 13 is a view of the gramophone turntable and pick-up arrangement. In the left-hand corner may be seen the recording microphone and a switch having four positions: Radio Reception, Radio Recording, Record Reproduction, and Home Recording.

Table Type Receiver

The receiver shown in Fig. 14 is a 10-valve superheterodyne of the table type. A rear view of the instrument is shown in Fig. 15, and indicates the compact arrangement of parts. As may be seen, the loud

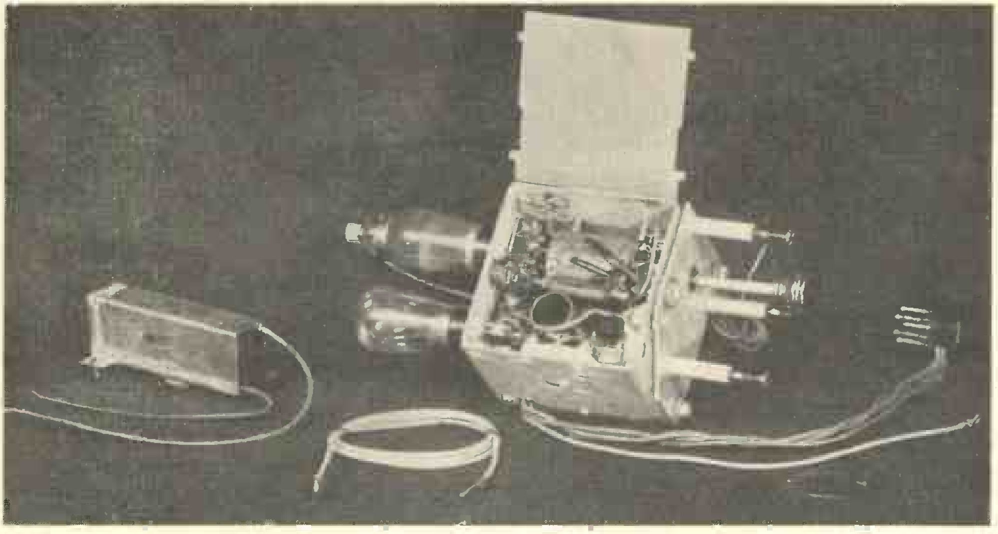


Fig. 24.—RCA Victor Model S.W.3.

This is a short wave converter. Note the compactness of this unit.

speaker is of the moving-coil type and relatively large.

" Baby " Midget Receiver

Figs. 16 and 17 show a receiver of the very small variety, employing a tuned radio-frequency type of circuit and a moving-coil loud speaker.

Automobile Receiver

The receiver shown in Figs. 18 and 19 is designed for installation in a motor car. It employs a superheterodyne circuit with automatic volume control. The use of a Class B type output amplifier, permanent-magnet loud speaker, and 6-volt valves having very low filament power consumption make this receiver an efficient one

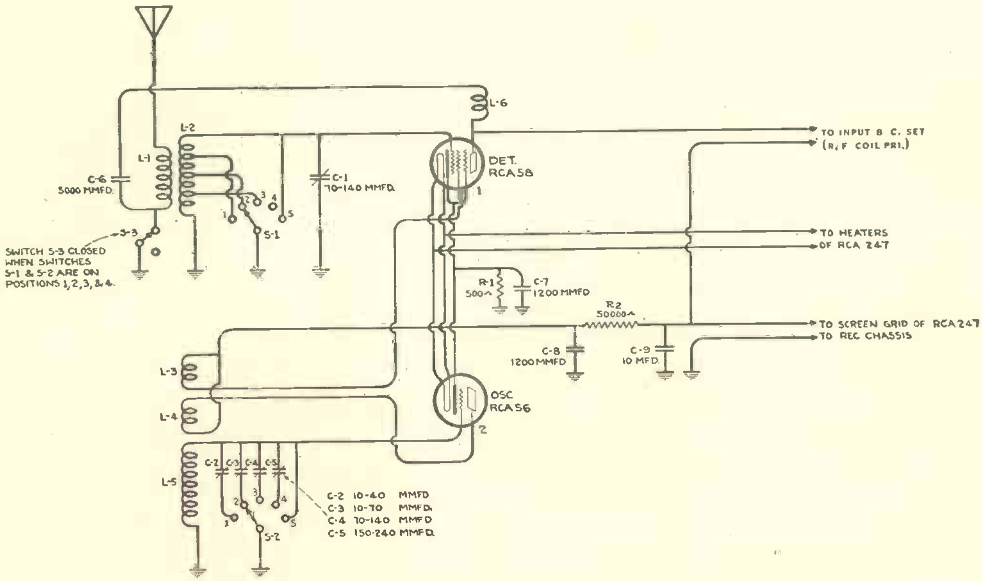


Fig. 25.—Circuit Diagram of RCA Victor Model S.W.3 Converter.

from the standpoint of current drain on the batteries. Filament current is supplied by the motor car storage battery, and the plate voltage is obtained from a dry battery or other source. The circuit diagram is shown in Fig. 20.

Combination Broadcast-Wave and Short-Wave Receiver

The receiver shown in Figs. 21 and 22 is a superheterodyne, designed for standard broadcast reception, in combination with a converter which will permit reception on the 19, 25, 31 and 49-metre bands. The theoretical diagram of the circuit is shown in Fig. 23. This converter is of the tuned type which supplies to the aerial circuit of the receiver signals at a fixed frequency, permitting the tuner of the latter to be left in one position.

Short-Wave Converter Attachment

A short-wave converter, designed to be mounted in the standard receiver cabinet, is shown in Fig. 24. As may be seen, it is very compact and requires only a small amount of space. The theoretical diagram in Fig. 25 shows this circuit to be of the fixed-tuned type, which applies to the aerial circuit of the receiver signals at various frequencies. The switch shown is used to select the waveband, and the standard receiver is used in tuning the system. Power for the valves is obtained from the receiver supply.

Present Trend is towards Refinements rather than Radical Changes in Circuits

From the foregoing it is apparent that the present trend of development in American broadcast receivers is towards refinements, making for improved performance and ease of operation, rather than towards radical changes in circuits or components. Economic conditions, and the highly competitive state of the industry, have caused manufacturers to make intensive efforts to reduce the cost and to improve the quality of these receivers until, at the present time, the values offered surpass those of any other period in the history of the industry.

WHAT TO DO WHEN MAINS TRANSFORMER TAPPINGS ARE NOT THE SAME AS THE SUPPLY VOLTAGE

MANY mains transformers are supplied with tappings for inputs of 200, 220, and 240 volts, and the question sometimes arises as to which of these should be used if the mains supply happens to be 230 volts. It will generally be found that either the 220 or the 240-volt tapping will be perfectly satisfactory. By connecting to the 220 tapping it is possible that the output voltages will be slightly higher, so that it may in some cases be better to use the 240 tapping. Should the mains supply voltage be rather less than its rated voltage then it would be a definite advantage to use the lower of the two tappings in question.

A simple test to ascertain definitely which of the two is most satisfactory is to test the anode current consumption of the valves. If these are too low when using the 240-volt tapping, then the readings will probably be just about correct when the 220-volt tapping is used.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc.(Lond.)

SECTION VI—THE EXTENSION OF OHM'S LAW

IN Section I. we considered Ohm's Law which we stated in the form of an equation, thus:—

$$E = IR \quad . \quad . \quad . \quad (1)$$

i.e., the voltage (E) produced across the ends of a wire, of resistance R, carrying a current I is equal to the product of I and R. In the case considered the current was a direct current and the voltage a steady, or direct, voltage. We have also stated (Section II.) that it is immaterial whether we think of the current as producing the voltage or of the voltage as producing the current, both are different aspects of the one event.

A.C. Circuit Calculations

If we connect a resistance in the circuit of an alternator so that an alternating voltage is applied across its ends, an alternating current will pass through the resistance. Provided that the circuit contains neither inductance nor capacity, the same relation exists between the voltage and current as exists in the case of the D.C. circuit, viz.:—

$$E = IR_{A.C.} \quad . \quad . \quad . \quad (2)$$

The suffix after the R denotes that the equation refers to an A.C. circuit. In this case E and I are either R.M.S. or peak values. It is immaterial which, provided that they are both the same. This is easily shown, for we have:—

$$E = \frac{E_0}{\sqrt{2}} \quad . \quad . \quad . \quad (3)$$

$$\text{and } I = \frac{I_0}{\sqrt{2}} \quad . \quad . \quad . \quad (4)$$

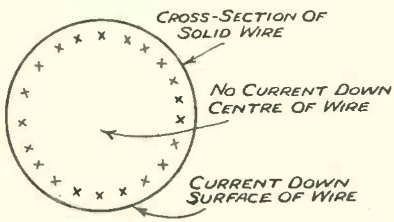


Fig. 1.—SHOWING HOW CURRENT TRAVELS ON THE SURFACE OF A WIRE IN AN A.C. CIRCUIT.

In (2) put in the values (3) and (4) for E and I, then:—

$$\frac{E_0}{\sqrt{2}} = \frac{I_0}{\sqrt{2}} R_{A.C.}$$

Cancelling the $\sqrt{2}$ from each denominator we have:—

$$E_0 = I_0 R_{A.C.},$$

which is an equation of the same type as (2) with peak values for voltage and current in place of R.M.S. values.

A.C. Resistance greater than D.C. Resistance

Now the resistance, $R_{A.C.}$, which the wire offers to the output from the alternator is not the same as the resistance which it offers in a D.C. circuit. The A.C. resistance of a wire is greater than its D.C. resistance, but in the case of alternating currents of power frequencies the increase from $R_{D.C.}$ to $R_{A.C.}$ is very small, and for almost all practical purposes the A.C. resistance can be taken to be the same as the D.C. resistance.

A Typical Example

In the case of frequencies greater than 2,000 or 3,000 cycles per second the increase in resistance is measurable, and the A.C. resistance is very often several times its D.C. counterpart. As an example consider the case of a 250 mH coil with a D.C. resistance of the order of 1·5 ohms. When tuned to 600 metres with a ·0005 mfd. condenser the A.C. resistance (of the coil only) to a signal of this wavelength — frequency = 500 kc/s — would be of the order of 4·0 ohms. It is important to note that we are here considering the actual resistance of the coil quite apart from any effects of resistance due to its inductance or to the capacity used for tuning.

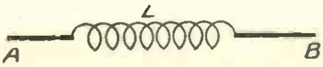


Fig. 2.—A CIRCUIT COMPRISING A COIL OF INDUCTANCE L HENRIES.

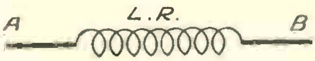


FIG. 3.—CIRCUIT COMPRISING A COIL OF RESISTANCE R OHMS AND INDUCTANCE L HENRIES.

What the "Skin" Effect is

The increase in resistance with frequency is due to what is known as a "skin" effect. In the case of a wire carrying direct current the current is equally distributed over the whole of the cross-section of the wire. In an A.C. circuit the current is forced to travel on the surface of the wire (see Fig. 1). The greater the frequency of the current the more pronounced the effect becomes—*i.e.*, the nearer to the surface the current is forced to travel. The extent of the effect varies with the material of which the wire is made and with the shape of the wire. In the case of a straight length of copper wire, if we denote the A.C. resistance at radio frequency by $R_{A.C.}$ and the D.C. resistance by $R_{D.C.}$, as previously, we have the following relation between these quantities :—

$$R_{A.C.} = [0{\cdot}097\, d\, \sqrt{f} + 0{\cdot}25] \times R_{D.C.} \quad . \quad (5)$$

where d is the diameter of the wire in inches and f is the frequency of the current in cycles per second.

How A.C. Resistance can be Calculated

Thus we see that if we know the D.C. resistance of a wire, its diameter, and the frequency of the current (or voltage), we can calculate the A.C. resistance. As an example, let us find the value of $R_{A.C.}$ when $R_{D.C.} = 2{\cdot}5$ ohms, $d = {\cdot}012$ inches, and the frequency is 1,000 kc/s. We have :—

$$R_{A.C.} = [0{\cdot}097 \times 0{\cdot}012 \times \sqrt{1{,}000{,}000} + 0{\cdot}25] \times 2{\cdot}5 \text{ ohms.}$$

i.e., $R_{A.C.} = [0{\cdot}097 \times 0{\cdot}012 \times 1{,}000 + 0{\cdot}25] \times 2{\cdot}5$ ohms.

i.e., $R_{A.C.} = 3{\cdot}5$ ohms (approx.).

This formula is only applicable to radio frequency calculations, and must not be applied to cases of audio and power frequencies.

The resistance with which we have been treating is often referred to as pure resistance to emphasise the fact that it has no connection with the resistance effects due to the inductance and capacity of a circuit.

Impedance

Professor Ohm discovered the law showing the relation between the current, voltage, and pure resistance of a circuit. Steinmetz discovered a law, which has been called the *Extension of Ohm's Law*, and which states the relation between the current, voltage, and the EFFECTIVE RESISTANCE of any circuit. The term IMPEDANCE is frequently used in place of effective resistance. The law is :—

$$E = IZ \quad . \quad . \quad . \quad (6)$$

where Z is the impedance of the circuit. Put into words, the equation states : "The voltage (E) produced across the ends of a circuit of impedance Z and carrying an alternating current I is equal to the product of I and Z." When E is measured in volts and I in amperes, the impedance Z is measured in ohms. E and I may be either R.M.S. or peak values, provided that they are both the same.

The Impedance of a Circuit

The impedance of a circuit is the resistance which results from the presence of some combination of inductance (L), capacity (C), and resistance (R) in the circuit, and there are, in all, seven ways of combining them, viz. :—

L only,
C only,
R only (Ohm's Law itself),
L and C,
C and R,
R and L,
L, C and R.

In each case there is

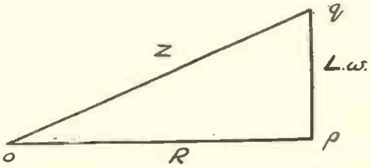


Fig. 4.—RIGHT-ANGLED TRIANGLE WHOSE SIDES REPRESENT $L\omega$, R AND Z OF FORMULA (9).

an infinite number of ways in which the inductance capacity and resistance may be connected. Thus, in the case of inductance only there may be one, two, three, and so on, inductances, all of different inductance value, connected in series, parallel, or in any series-parallel combination. The same applies to the more complex arrangements. We shall consider only the simpler cases frequently encountered in radio circuits.

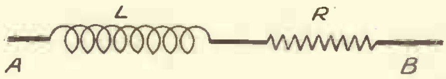


Fig. 5.—A PURE INDUCTANCE OF L HENRIES JOINED IN SERIES WITH A PURE RESISTANCE OF R OHMS.

Properties possessed by every Length of Wire

In actual practice every length of wire and every coil possess both pure resistance and pure inductance. In a great many cases, however, the effect of either resistance or inductance is so great as to swamp the effect of the other. A pure inductance is the term applied to a coil of which the resistance is negligible. In the case of condensers every condenser behaves in a circuit as though it comprises both pure capacity and pure resistance, but the effect of the resistance component is generally small and will be neglected for the present.

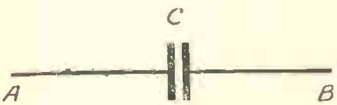


Fig. 6.—CIRCUIT SHOWING A PURE CAPACITY C.

What the Impedance of a Circuit consists of

The impedance of a circuit consists of two parts: (1) the pure resistance, and (2) the REACTANCE. The latter is the effect of the pure inductance and the pure capacity of the circuit apart from the pure resistance. In simple circuits the reactance depends on the value of the inductance, the capacity, and the frequency of the current in the circuit. In considering the simple cases of impedance we shall express the results in the form of equations and we shall employ X and Z as a shorthand notation for reactance and impedance respectively. We shall find that the term $2\pi f$ occurs very frequently throughout all impedance calculations and the mathematician saves time by writing the Greek letter "w" pronounced "omega," as shorthand for $2\pi f$. That is, he makes the substitution $w = 2\pi f$, and wherever he sees $2\pi f$ he writes w.

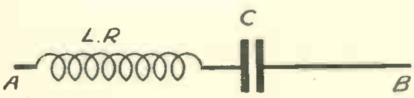


Fig. 7.—CIRCUIT COMPRISING A COIL AND CONDENSER CONNECTED IN SERIES.

Fig. 2 shows a circuit comprising a coil of inductance L henries. The reactance of the circuit across the terminals A and B is:—

$$X = L \times 2\pi f \text{ ohms} \quad . \quad (7)$$

where f is the frequency of the current and π has the usual value of 3·1416. When L is in henries the reactance is expressed in ohms. There is no pure resistance in the circuit and the impedance is thus equal to the reactance:—

i.e., $Z = X$

∴ $Z = L \times 2\pi f$ ohms . (8)

Writing w for $2\pi f$ in (7) and (8) we have:—

$$X = Lw \text{ ohms} \quad . \quad (7a)$$

and $Z = Lw$ ohms . (8a)

Now suppose that the coil has a resistance of R ohms as well as inductance L henries (see Fig. 3). As before, the reactance is:—

$$X = Lw \text{ ohms.}$$

The pure resistance is R ohms, and the impedance is:—

$$Z = \sqrt{R^2 + (Lw)^2} \text{ ohms} \quad . \quad (9)$$

An example of this formula is given later.

Note that this equation reminds us of a certain well-known theorem in geometry, viz., Pythagorus' Theorem. If Z were the length of the hypotenuse of a right-angled triangle and R and Lw were the other two sides (see Fig. 4), then:—

$$\text{Hypotenuse} = \sqrt{(\text{1st. side})^2 + (\text{2nd side})^2} \quad . \quad (10)$$

i.e., $Z = \sqrt{R^2 + (Lw)^2}$.

If we have a pure inductance of L henries joined in series with a pure resistance of R ohms as in Fig. 5, the reactance is:—

$$X = Lw \text{ ohms}$$

and the impedance between A and B is :—

$$Z = \sqrt{R^2 + (Lw)^2} \text{ ohms.}$$

This equation is the same as (9) *hence we must conclude that the effect is the same as that of a coil and no additional resistance, the coil possessing both the inductance and resistance* (see Fig. 3).

The circuit of Fig. 6 shows a pure capacity C. The reactance of the circuit is :—

$$X = \frac{1}{Cw} \text{ ohms} \quad . \quad (11)$$

(NOTE.—The reactance is in ohms if C is in *farads*.)

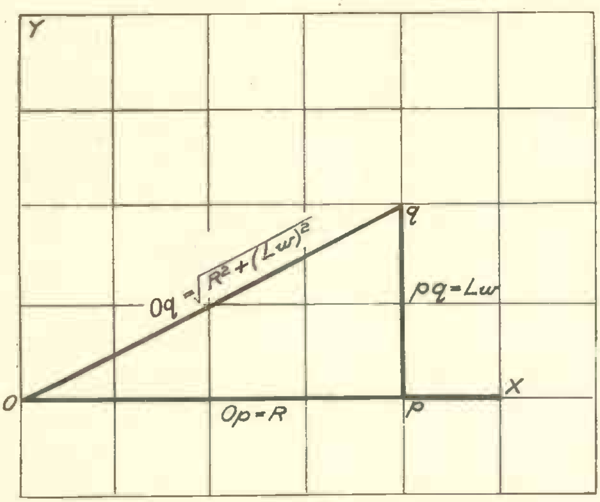


Fig. 8.—SHOWING HOW THE IMPEDANCE OF A CIRCUIT CAN BE EXPRESSED BY A TRIANGLE.

There is no pure resistance, hence the impedance equals the reactance :—

i.e., $X = Z$,

$$\therefore \quad Z = \frac{1}{Cw} \text{ ohms} \quad . \quad (12)$$

Coil and Condenser in Series

We will consider one more case, viz., that of a circuit comprising a coil and condenser connected in series, the coil possessing inductance and resistance and the condenser possessing pure capacity only (Fig. 7). In this case we have :—

$$X = Lw - \frac{1}{Cw} \text{ ohms} \quad . \quad (13)$$

and

$$Z = \sqrt{R^2 + \left(Lw - \frac{1}{Cw}\right)^2} \text{ ohms} \quad . \quad (14)$$

Impedance of a Low-frequency Choke

In all these cases we have merely stated the resulting reactance and impedance without proving the statements and without even indicating how the result is obtained.

We have neither space nor time here, however, to consider these points and the results must be accepted as established. In illustration of the application of the equations let us find the impedance of a low-frequency choke of inductance 30 henries and resistance 400 ohms. Since the impedance also depends on the frequency of the alternating current we must state the frequency at which the impedance is required. Let us find it for frequencies of 50 and 400 cycles per second.

Case 1.—($f = 50$).

The reactance is :—

$$X = Lw \text{ ohms.}$$

and writing in the values of L and ω we have :—

$$X = 30 \times 2 \times 3{\cdot}14 \times 50 \text{ ohms,}$$

i.e., $X = 9{,}420$ ohms.

If the choke possessed no resistance its impedance at 50 cycles per second would be the same as its reactance, viz., 9,420 ohms. Putting $R = 400$ in equation (9), we have :—

$$Z = \sqrt{400^2 + 9{,}420^2} \text{ ohms,}$$

i.e., $Z = \sqrt{88{,}881{,}000}$ ohms,

or $Z = 9{,}430$ ohms.

That is to say, the effect of the 400 ohms pure resistance is only 0·1 per cent. of the effect of the reactance, or negligible for all practical purposes. We should give the impedance as 9,420 ohms and neglect entirely the effect of the 400 ohms. It is not necessary to work out the somewhat difficult square root in order to discover whether R is small enough in comparison with Lw to be neglected. Provided that the one term in the square root expression is less than $\frac{1}{8}$th of the other the smaller term may always be neglected.

Case 2.—($f = 400$).

The reactance is :—

$$X = Lw \text{ ohms.}$$

i.e., $X = 30 \times 2 \times 3{\cdot}14 \times 400$ ohms.

or $X = 75{,}360$ ohms.

In this case the 400 ohms resistance is certainly less than $\frac{1}{8}$th of the 75,360 ohms reactance, and hence will be neglected in the final answer. The impedance for a frequency of 400 cycles is thus :—

$$Z = 75{,}360 \text{ ohms.}$$

Impedance of a 2 mfd. Condenser.

Let us also find the impedance of a condenser of capacity 2 mfd. at frequencies of 50 and 300 cycles per second. From (11) we have :—

Case 1.—($f = 50$).

$Z = \frac{1}{Cw}$ ohms, when C is measured in *farads.*,

i.e., $Z = \frac{1}{Cw} \times 10^6$ ohms, when C is measured in *microfarads.*

writing in the values of C and ω we have :—

$$Z = \frac{1}{2 \times 2 \times 3{\cdot}14 \times 50} \times 10^6 \text{ ohms,}$$

i.e., $Z = 1{,}590$ ohms (approx.)

Case 2.—($f = 300$)

$$Z = \frac{1}{2 \times 2 \times 3{\cdot}14 \times 300} \times 10^6 \text{ ohms,}$$

i.e., $Z = 265$ ohms (approx.)

It will be seen from these examples that (1) an increase in frequency causes an increase in impedance in the case of an inductance, and *vice versâ*, and (2) an increase in frequency causes a decrease in impedance in the case of a capacity, and *vice versâ*. These two facts are highly important in radio design and they explain, for instance, why the efficiency of intervalve couplings varies with the frequency. We shall refer to this again in later articles when we deal with tuning and with further examples of impedance in connection with amplifier design.

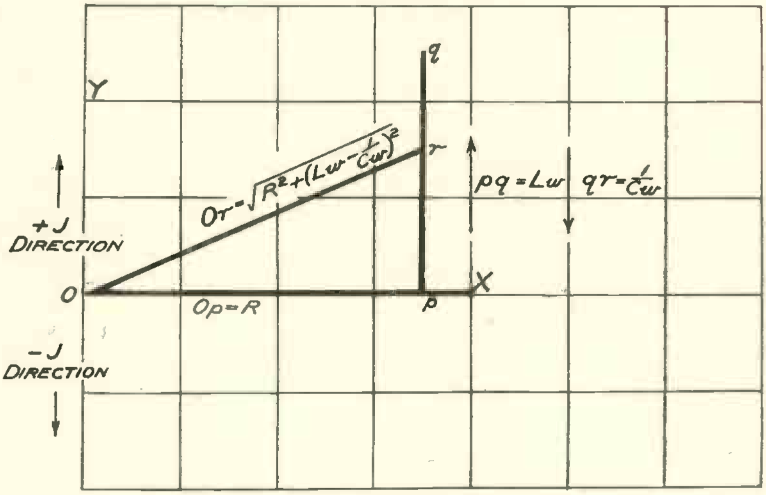


Fig. 9.—SHOWING HOW THE IMPEDANCE IS REPRESENTED BY THE HYPOTENUSE OF THE RIGHT-ANGLED TRIANGLE.

Another form of expressing Impedance

There is another form in which the impedance of circuits can be expressed. We have already noted that the equations we have obtained are similar in form to the equation expressing the result of Pythagorus' Theorem. Let us take a piece of squared paper and draw two axes, OX and OY, and measure resistance along the OX axis and reactance along the OY axis. In Fig. 8 the triangle O*pq* was obtained by measuring first a length O*p* along OX equal to R ohms, and then a length *pq*, parallel to OY (*i.e.*, perpendicular to OX), equal to L*w*. The line O*q* then represents the impedance of the circuits of Figs. 3 and 5. We may write this operation as follows :—

O*q* = result of O*p* (= R) along OX and *pq* (= L*w*) upwards and parallel to OY.

Let us use a shorthand notation to

abbreviate this statement. We may write :—

$$Oq = (R) \text{ and } (+\,jLw) \qquad . \ (15)$$

In this equation the letter j denotes than the length Lw is measured in a direction perpendicular to OX, *i.e.*, perpendicular to R, and the + sign indicates that the direction of Lw is upwards. When this form of expressing the impedance is employed a small letter z is used for impedance, and both the brackets and the word " and " are omitted. Thus we have finally :—

$$z = R + jLw \qquad . \ (16)$$

Putting this back into words, we have:— " The impedance of the circuit is represented by the hypotenuse of a right-angled triangle of which the other two sides represent the resistance and the reactance respectively."

In the case of the circuit of Fig. 7 we have the following equation as the impedance equation :—

$$z = R + j\left(Lw - \frac{1}{Cw}\right) \qquad (17)$$

This states that the impedance is represented by the hypotenuse of the right-angled triangle which has sides representing R and $\left(Lw - \frac{1}{Cw}\right)$ respectively. The diagram showing this operation is given in Fig. 9. The length Op along OX represents R and the length pr parallel to OY represents the reactance of the circuit. This is split into two parts, the positive part due to the inductance L and equal to $(+Lw)$, and the negative part due to the capacity C and equal to $\left(-\frac{1}{Cw}\right)$. These two parts are shown in the figure by the line pq in the upwards, or $+\,j$, direction, and the line qr in the downwards, or $-\,j$, direction.

Vector Representation and Vector Impedance

This representation of the impedance of a circuit is known as the VECTOR REPRESENTATION, and the quantity z is called the VECTOR IMPEDANCE. The vector impedance becomes the actual impedance of the circuit when we draw the right-angled triangle and express the length of the hypotenuse (representing z) in terms of the other sides (representing the reactive and non-reactive components of the circuit). This representation is important and will be referred to again.

WHAT TO DO WHEN AN ELECTRIC RADIOGRAM MOTOR WILL NOT SWITCH ON

SHOULD the motor of an electric radiogram fail to rotate when switched on, it should be switched off and tested to see if it can be rotated by hand. If it moves round quite freely then the most probable source of trouble is a broken electrical contact or switch. Look at the switch contacts and see if they are dirty or appear to be burnt. Any dirt should be removed by cleaning with glasspaper or a fine file.

With the motor switched on again, test across the motor terminals with a voltmeter. If a reading is obtained, then a fault in the motor itself is indicated. This might be a broken connection between terminals and brushes or field coils, or a brush may be stuck in its holder.

If, however, the turntable feels stiff when rotated by hand then the trouble is probably of a mechanical nature. Often a spot of oil will put the matter right unless any obvious fault such as a broken governor spring entangled in something can be seen. Other points to look for are stiff bearings, and in the case of commutator motors, dirty commutator and brushes.

THE DUAL PURPOSE THREE

By EDWARD W. HOBBS, A.I.N.A.

THE Dual Purpose Three, a self - contained battery-operated set shown in Fig. 1 has remarkably good tonal qualities associated with a silent background and ample choice of alternative British and Foreign programmes.

Fig. 1.—THE COMPLETED SET.

Contained within this handsome dome-topped case is the complete receiver with batteries and moving-coil loud speaker.

Special Features

Amongst the various features which distinguish this effective set are choice of reaction on aerial or grid coil; tonal qualities, a selectivity enabling the reception of Muhlacker free from interference from London and *vice versâ,* when tested on the outskirts of London in conjunction with a good earth and an indifferent indoor aerial.

Single knob tuning is employed for all normal reception, but a trimmer condenser is incorporated for final tuning of weak foreign stations; a practical method that brings them in at maximum strength.

A permanent magnet moving-coil loud speaker associated with a parallel-feed transformer - coupled power valve ensures ample volume.

Ganged dual range coils of first class make add their quota to the general overall efficiency of the set. Neat plug and socket fittings are provided for aerial and earth leads and for the gramophone pick-up leads.

Materials Required

The following comprises a complete list of components and materials required for this set.

COILS.—2 Type ATG/R (" *Lewcos* ").

TUNING CONDENSER.—1 "Unitune" 2-gang ·0005 mfd. (*Jackson Bros.*).

REACTION CONDENSER.—1 Popular Log. ·00025 mfd. (*Jackson Bros.*), with Brown colour knob.

AERIAL CONDENSER.—1 " Lewcodenser," Type W (" *Lewcos* ").

CHOKES.—1 H.F.C. super (" *Lewcos* ") ; 1 Midget H.F. (" *Lewcos* ").

TRANSFORMER.—1 Type L.F. T. No. 6A (" *Lewcos* ").

FIXED CONDENSERS.—1 2-mfd. (*T.C.C.*) ; 1 1-mfd. (*T.C.C.*) ; 1 ¼-mfd. (*T.C.C.*) ; 1 ·0001-mfd. (*T.C.C.*) ; 1 ·0001-mfd. with G.L. clips (*T.C.C.*).

GRID LEAK.—1 megohm (" *Telsen* ").

RESISTANCE.—1 25,000-ohm spaghetti (" *Lewcos* ").

SWITCHES.—1 Gramo-off-Radio switch (" *Bulgin* ") ; 1 Two-way-and-off.

LOUD SPEAKER.—Permanent magnet

M.C., No. D.9 (" *Igranic* ").

VALVES.—1 S215 A Metallised ("*Mazda*"); 1 H.L. 2 Metallised ("*Mazda*"); 1 P220 A (" *Mazda* ").

VALVE HOLDERS.—3 4-pin Anti-microphonic (" *Ultra* ").

BATTERIES.—1 Gel-Cel No. J.W.F.7 " Exide " ; 1 " Drydex " H.T. and G.B. combined, No. H1038 (" *Exide* ").

CABINET.—American type, No. 30, Oak (" *Stenibac* ").

BATTERY CORD. — 8-way and wander-fuse (" *Belling Lee* ").

1 Aerial-Earth, Twin Socket Strip (" *Belling Lee* ") ;

1 " Pick-up " Twin Socket Strip (" *Belling Lee* ") ;

1 H.T. + 3 Terminal (" *Belling Lee* ").

BASEBOARD.—1 14-inch by 9 by $\frac{1}{2}$ inch (" *Sinclairs* ").

SUB-BASE.—1 piece 5 inches long, $4\frac{3}{4}$ inches wide, $\frac{3}{8}$ inch thick (" *Sinclairs* ").

COIL BLOCKS.—2 $2\frac{1}{2}$ by $3\frac{1}{4}$ by $\frac{3}{8}$ inches (" *Sinclairs* ").

BEARERS.—2 $1\frac{1}{2}$ by $\frac{1}{2}$ by 9 inches (" *Sinclairs* ").

WIRE.—2 coils " Glazite " wiring (" *Lewcos* ") ; 4 yards " Lewcoflex " (" *Lewcos* ").

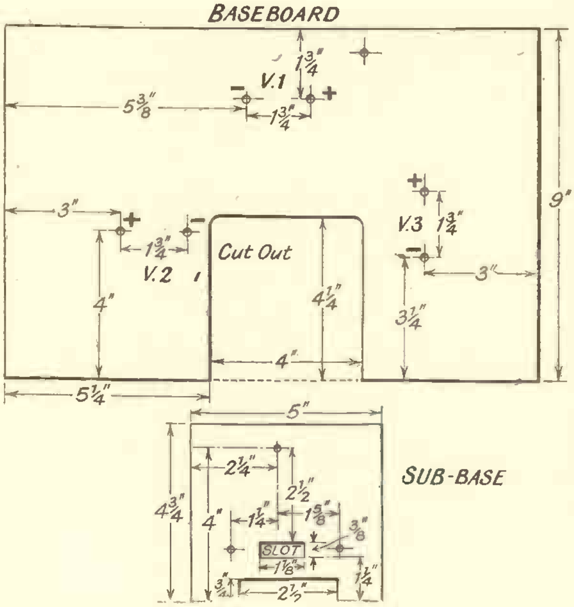


Fig. 2.—PLAN OF BASEBOARD AND SUB-BASE.

The sub-base screws underneath the baseboard and is drilled for the fixing lugs on the condenser. The holes in the baseboard are for the L.T. wiring.

What to do First

Having obtained all the components examine them to see they are perfect and as specified; then proceed to screw the bearers to the inside of the cabinet, placing their top edges 4 inches from the bottom of the inside of the cabinet. See that the baseboard will rest nicely upon the bearers without rocking.

Preparing the Baseboard

The baseboard is a piece of smooth pine 14 inches long, 9 inches wide and $\frac{1}{2}$ inch thick; it has to be cut to shape as shown in Fig. 2, and the various holes drilled for the subsequent passage of the L.T. wires. The sub-base screws underneath the opening in the baseboard.

The makers of the " Unitune " condenser supply full size templates which must be used when drilling the sub-base for the holding-down lugs which project from the bottom of the condenser casing.

Turn the baseboard upside down and cut grooves in it connecting the holes drilled for the L.T. leads—as shown in Fig. 3—doing this either with a chisel or a sharp penknife.

Next, cut out the slot in the sub-base for the front trimmer condenser blades to rotate in and see that they can turn quite freely.

Raising the Coils

The next step is to prepare two blocks of wood each measuring $2\frac{1}{2}$ inches wide, $3\frac{1}{4}$ inches long and $\frac{3}{8}$ inch thick. Glue or screw them to the top of the baseboard in the positions indicated in the diagram, Fig. 2, and as sketched in Fig. 6, which shows

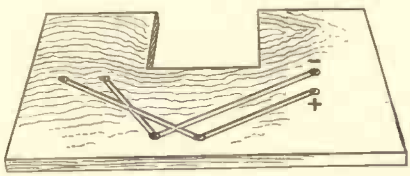


Fig. 3.—UNDERSIDE OF BASEBOARD.

Grooves are cut as here shown for the L.T. wires to the valve filaments.

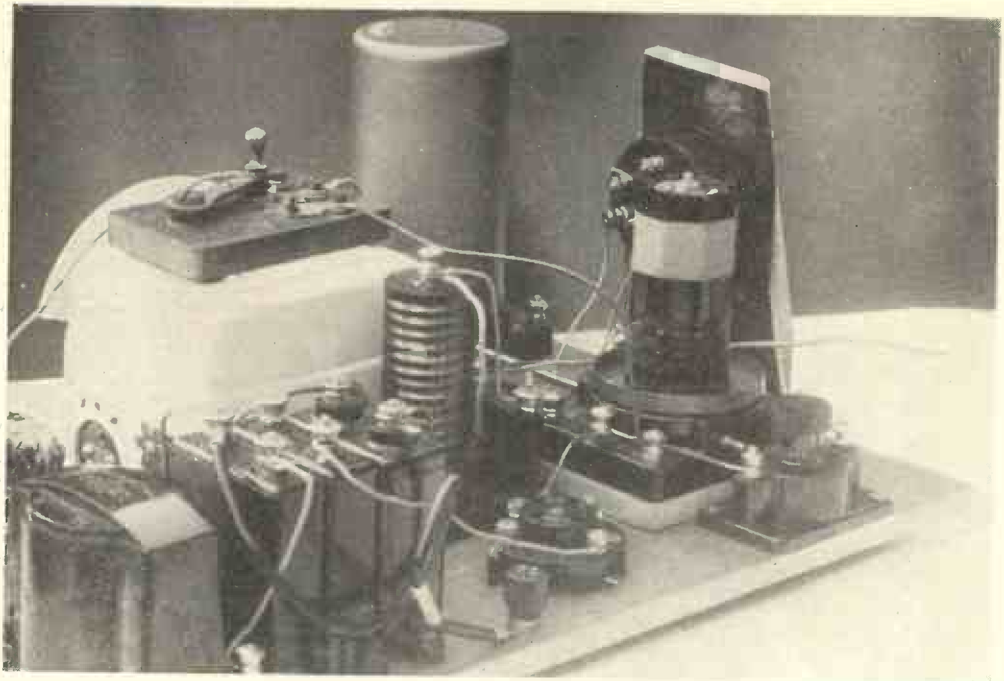


Fig. 4.—TEMPORARY SUPPORT FOR SWITCH.

The switch is held by a temporary piece of wood nailed to the baseboard. This ensures neat and efficient wiring.

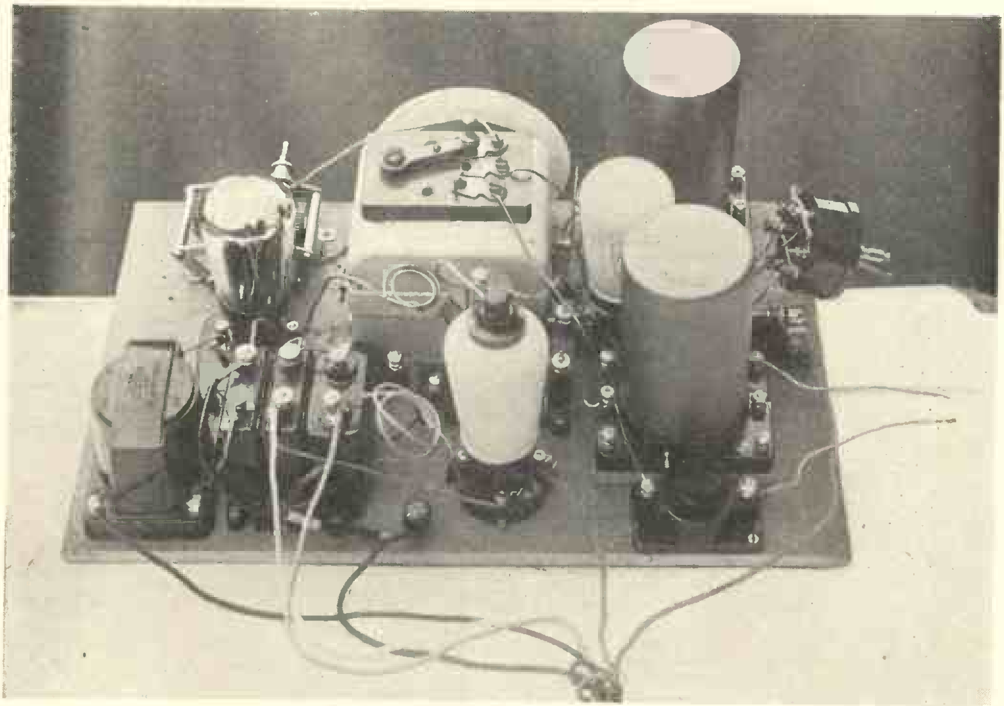


Fig. 5.—PLAN VIEW OF WIRING.

The complete receiver on baseboard wired up ready to insert in the cabinet. The two coiled flexible wires are the leads to the loud speaker.

the baseboard prepared ready for the assembly of the components.

Fasten the "Unitune" condenser to the sub-base by first putting an $\frac{1}{8}$-inch thick ebonite washer over each lug, then put the lugs through the holes in the baseboard and secure them as shown in Fig. 7, with large diameter ebonite washers and screws.

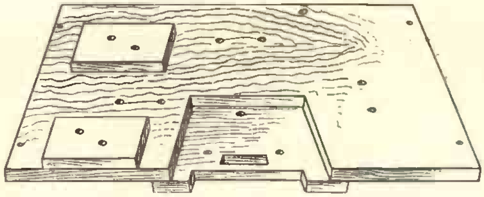


Fig. 6.—BASEBOARD WITH COIL BLOCKS AND SUB-BASE.

Here is shown the complete baseboard ready for the components to be fitted.

Reaction Condenser and Switch

The reaction condenser has next to be mounted to the right of the "Unitune," and it is held down to the baseboard by two metal straps—as shown in Fig. 8—but take care to keep the spindle at right angles to the front edge of the baseboard and note that the framework is not distorted in any way while fastening it down, as should distortion occur the moving vanes may touch the fixed ones and cause a short-circuit. The two-way-and-off switch is fastened to the top of the "Unitune" case by a single screw driven from beneath through a hole in the case.

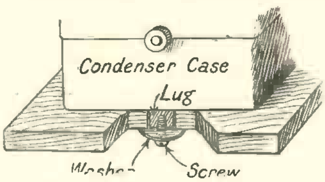


Fig. 7.—DETAIL SHOWING CONDENSER FIXING.

The condenser is held down by screws and washers which clamp against the underside of the sub-base. The screws fit into lugs on the case.

Mounting the Coils

The "Lewcos" coils used in this set have a wavechange switch incorporated in the base, and this is so arranged that the two coils can be ganged by the simple process of putting them in line and passing a long rod, supplied with the coils, through both the switches.

Put both coils on their respective blocks, with terminals Nos. 1–2–6 towards the "Unitune," then put the switch rod through the bases of both, and screw them down, taking care to see that they are in line, and testing this by moving the rod backwards and forwards.

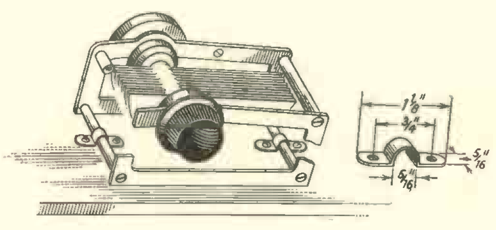


Fig. 8.—STRAPS FOR FIXING CONDENSER.

The condenser is shown partly broken away to reveal the straps screwed to the baseboard and clamping down the tie rods on the condenser frame.

Work on the Panel

A separate panel is neither necessary nor is it provided on this set, the components are mounted directly on the baseboard, but holes must be drilled in the front of the case to clear the control spindles as shown in Fig. 9, and an aperture for the escutcheon must be cut out—as shown in Fig. 10—the exact position being located by means of the template supplied with the condenser.

The exact location of the holes for the condenser spindles and the wave-change spindle should be checked by putting some chalk or white paint on the ends of the spindles and then putting the baseboard into place and pressing it forwards when white marks will be made on the inside of the cabinet.

Drill fine holes through the centres of these marks, then enlarge the holes by drilling from the front.

Fitting the Escutcheon

Locate the position of the escutcheon by placing the template on the cabinet front and marking off the centre of the $1\frac{7}{16}$ inch diameter hole for the escutcheon.

Bore this with a centre bit or cut it out with a keyhole saw and fasten the escutcheon with the

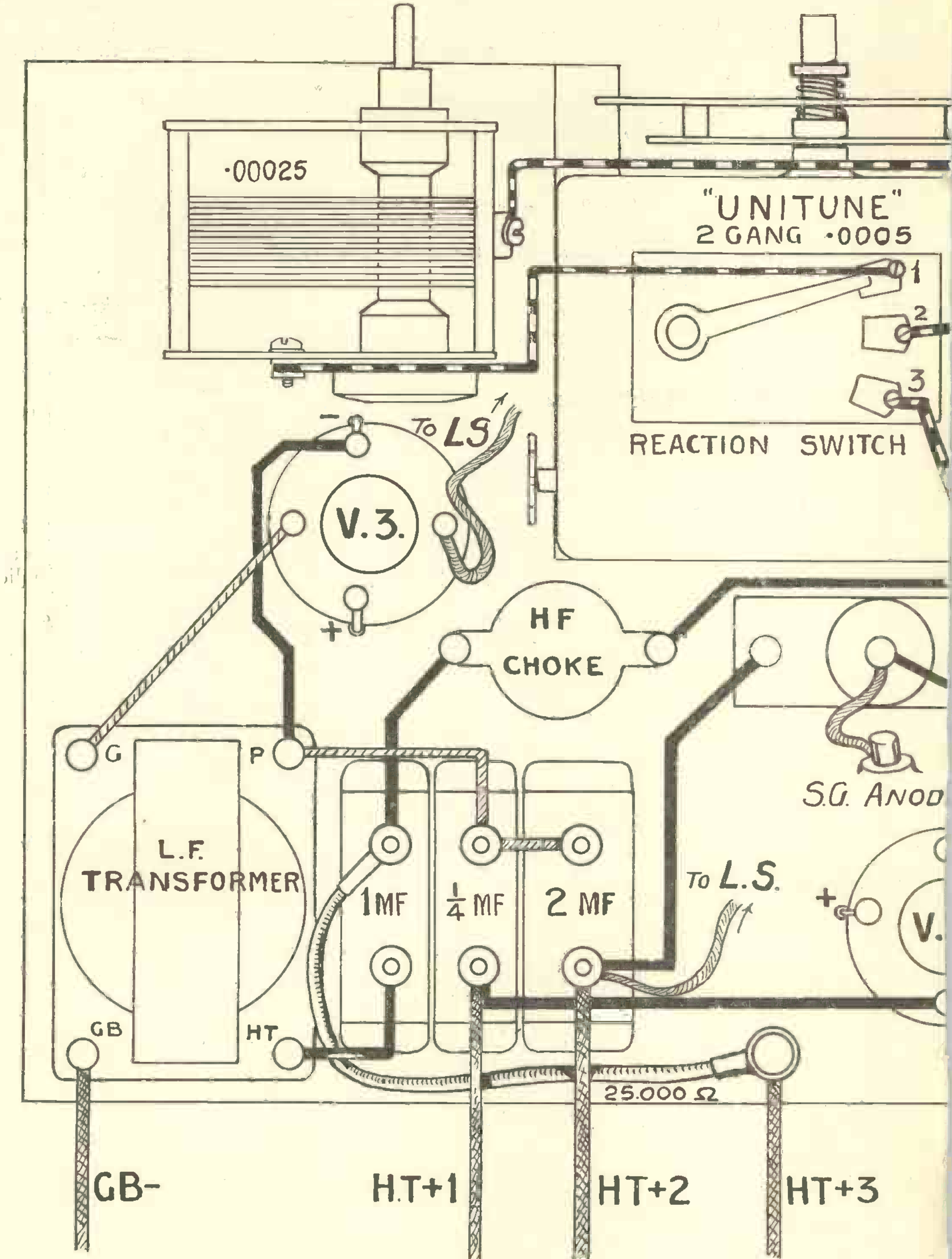
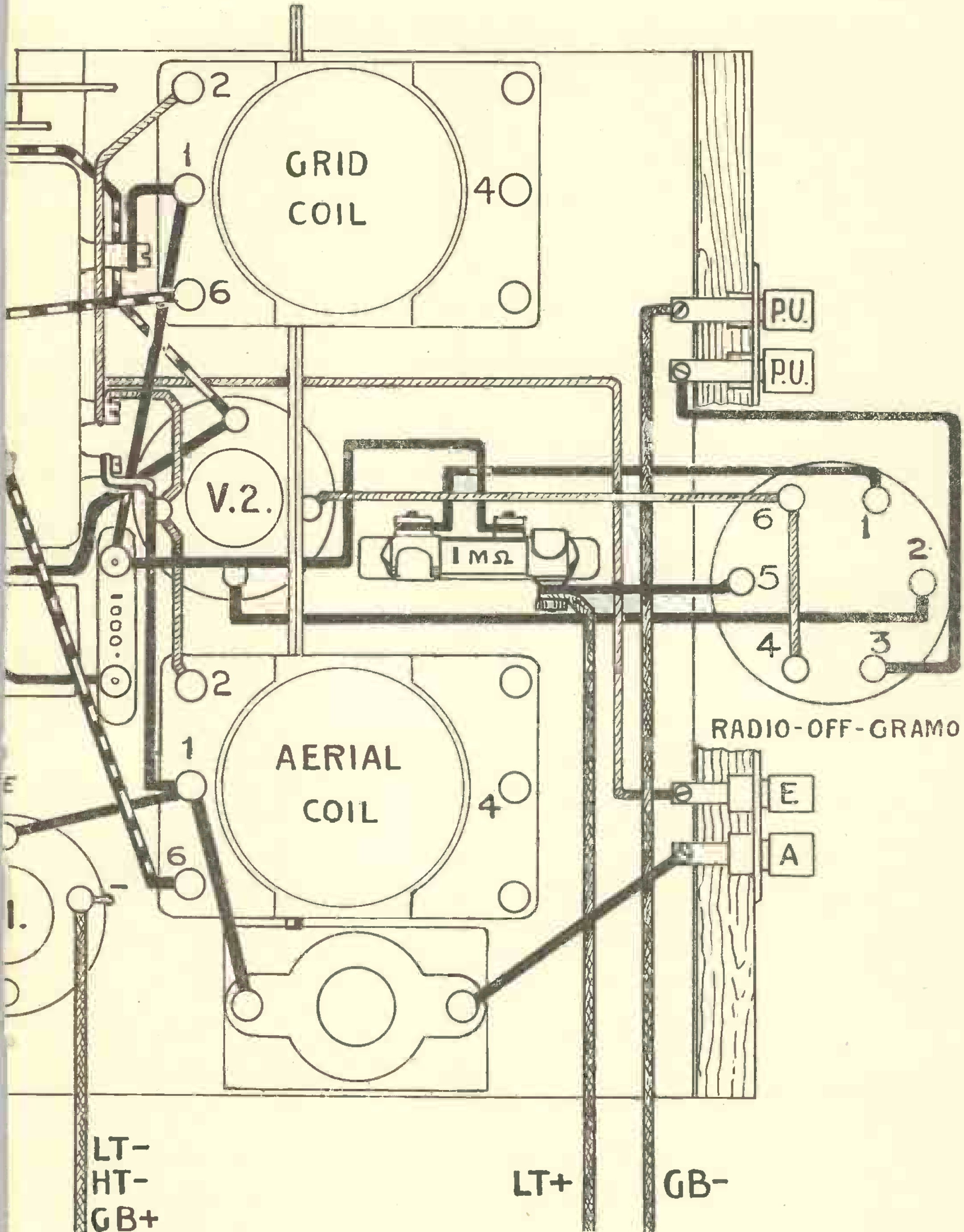


Fig. 8A.—Wiring Plan of

This wiring plan, in conjunction with the point-to-point wiring in



THE DUAL PURPOSE THREE.

structions, should make the wiring of this receiver an easy matter.

clamp and screw provided.

Note that the hole for the spindle should be $\frac{7}{8}$ inch diameter to allow ample clearance for the slow-motion device.

Try the baseboard in place to see that everything is correct and that all controls can be operated freely.

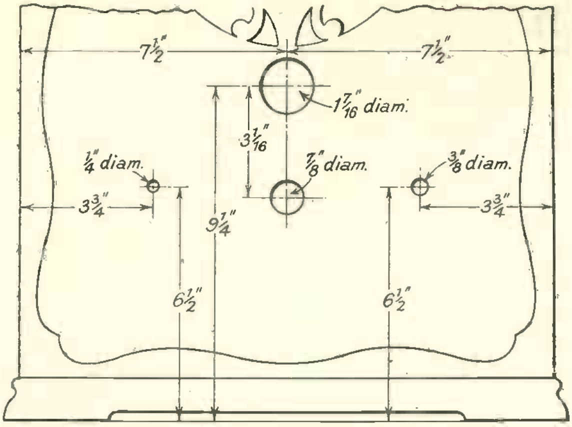


Fig. 9.—Drilling Details for Cabinet Front.

Lower part of the cabinet showing centres of holes for control spindles and escutcheon.

Fixing the Loud Speaker

A baffle board is provided in the "Stenibac" cabinet, and this should first be glued and screwed firmly in place, then the "Igranic" loud speaker is screwed to it with four round-headed brass screws $\frac{3}{4}$ inch long. Place the speaker so that the input transformer comes on the left, as seen from the back and as shown in Fig. 12, which gives a good impression of the progress of the work at this stage.

Fittings on Side of Cabinet

The aerial and earth terminal strips and those for the pick-up as well as the combined "Radio-off-gramo" switch are located on the right-hand side of the cabinet—as seen from the front — and are placed as shown on the dimensioned sketch Fig. 11—and are fixed in the usual way, the switch with a single nut, the Belling Lee terminal strips by small screws.

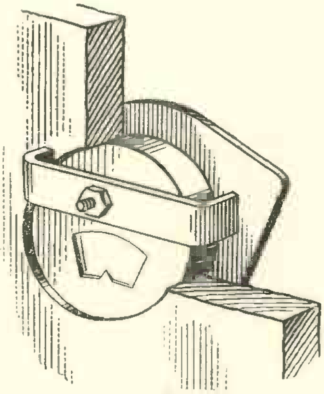


Fig. 10.—Fitting the Escutcheon.

The escutcheon fits into a circular hole in the cabinet, and is held in place by a stud and clamp.

Holes for the two bushes on these strips may be $\frac{3}{8}$ inch diameter and spaced $\frac{1}{2}$ inch apart, centre to centre. They are neat little fittings and have the practical advantage that they facilitate wiring, as will be explained later.

Assembling the Components

The positions of the components on the baseboard are clearly shown in Fig. 13, and this arrangement should be adhered to, although it is somewhat unorthodox.

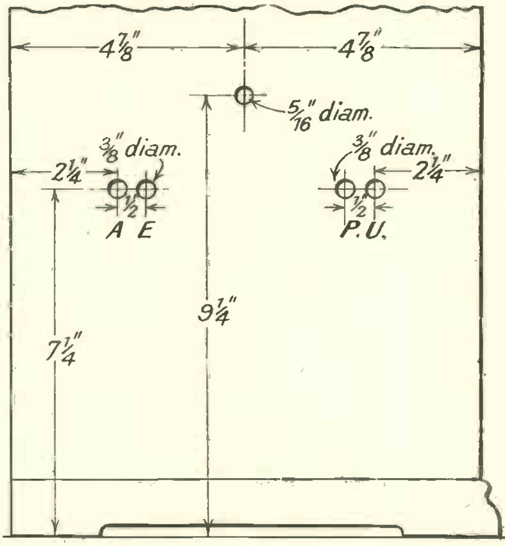


Fig. 11.—Fittings on Cabinet Side.

The switch, aerial and earth leads and the pick-up plug fittings are located on the left of the cabinet.

The first valve is placed centrally at the back of the base, the detector is on the left between the coils, the last or power valve on the right near to the L.F. transformer, the whole being thus arranged to ensure maximum efficiency.

Under Base Wiring

Having screwed down the valve holders, connect the filament terminals by running wires under the base, in the grooves already cut, and making connections to the terminals by bringing the wire up through the holes already drilled. Take care to connect the L.T. negative to the right-hand side terminal, as seen when looking down on the holder, with the grid at the top and the plate terminal at the bottom.

This is important because the "Mazda" metallised valves are earthed to terminal No. 3 on the valve, and this terminal should therefore be connected to earth to attain the maximum advantage from the metallisation, which acts as an efficient screen.

Screw all the components into place, then rig up a temporary piece of wood to support the radio-off-gramo switch while the wiring is in progress. This support can be any odd slip of wood nailed to the edge of the base, as shown in Fig. 4, provided it has a fixing hole for the switch in the corresponding place to that in the cabinet. The use of this temporary support facilitates the wiring of the switch and ensures the shortest possible leads to the grid and other parts.

Fig. 12.—LOUD SPEAKER IN CASE.

The loud speaker is screwed to the baffle board which is fixed in the upper front of the cabinet.

The Circuit

The circuit is shown in Fig. 14 in the customary theoretical form, while a plan view of the actual wiring of the receiver is given in Fig. 5 and a large scale wiring plan in Fig. 8A, which with the aid of the following point to point wiring instructions should remove any doubts as to their correct arrangements.

Point to Point Wiring

Before actually connecting any wires, remove the terminal from the right side of the "Unitune" condenser and put it in the corresponding place on the left—opposite the coil—also fit a screw into one of the tapped holes in the case above the terminal, but see that it does not touch the vanes inside the case.

Make the connections with "Glazite" wiring, except those to the pick-up and aerial-earth sockets, which should be wired with flexible wire, as should the two loud speaker leads and that to the anode of the first valve.

(1) Connect plate terminal of first valve holder V1 to $\frac{1}{4}$ mfd. condenser.

(2) Grid of V1 to No. 1 of aerial coil, the one farthest from panel, and thence to "Lewcondenser" and first terminal of "Unitune" condenser.

(3) Top of H.F. choke to ·0001 mfd. coupling condenser, other terminal of coupling condenser to grid condenser and to No. 1 of grid coil, and to second terminal of "Unitune" condenser.

(4) G. of detector valve V2 to No. 2 on switch.

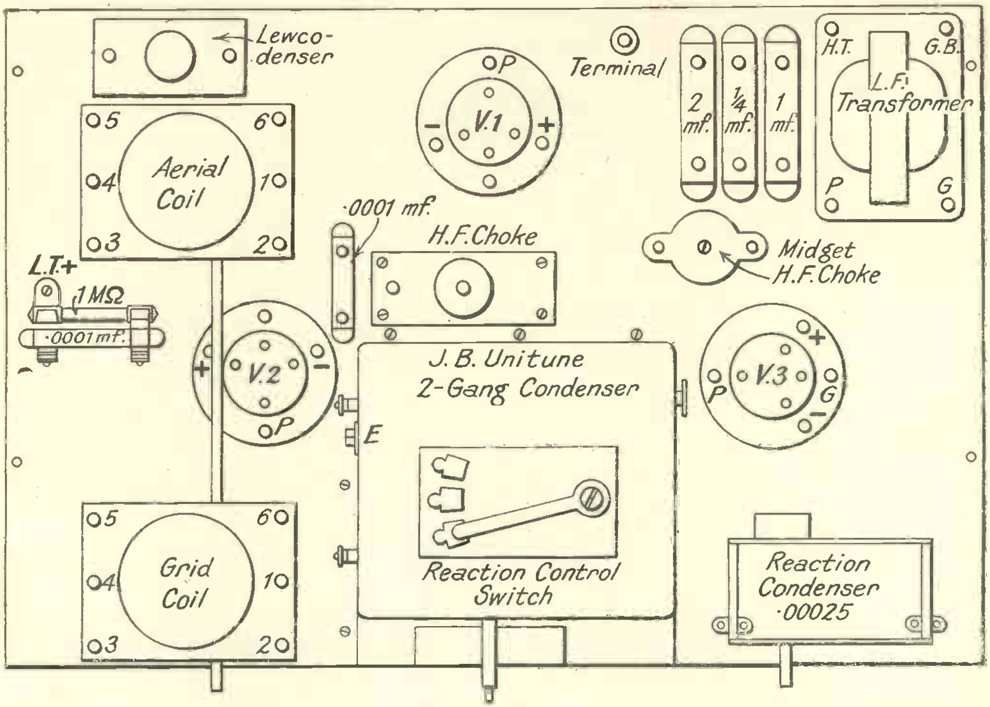


Fig. 13.—Components on Baseboard.
This shows the best arrangement of the components on the baseboard.

No. 5 of switch to free end of grid leak and L.T. + .

No. 1 of switch to free end of grid condenser.

(5) Connect together No. 4 and No. 6 of switch and take wire on to L.T. + terminal of V2.

(6) Plate of V2 to midget choke. Plate of V2 to fixed plates of reaction condenser.

(7) Connect L.T. negative terminal of

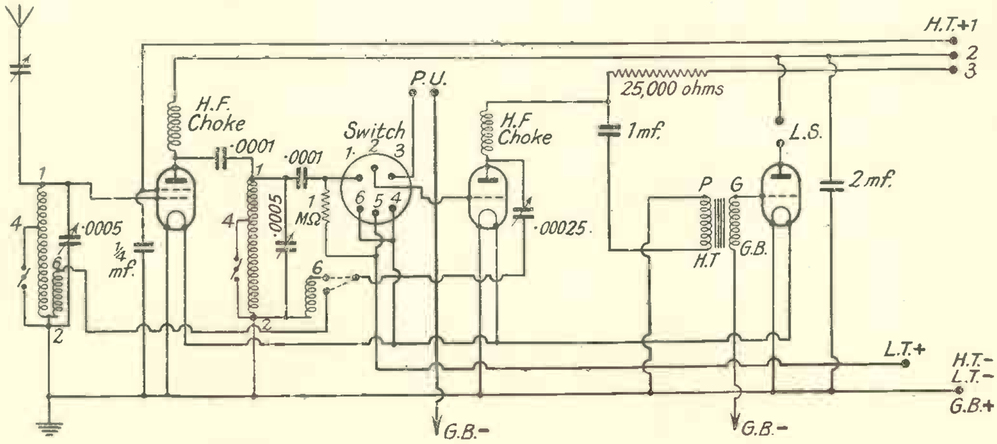


Fig. 14.—The Dual Purpose Three Circuit Diagram.
The circuit embodies modern ideas and makes provision for aerial or grid reaction and a gramophone pick-up for the electrical reproduction of records.

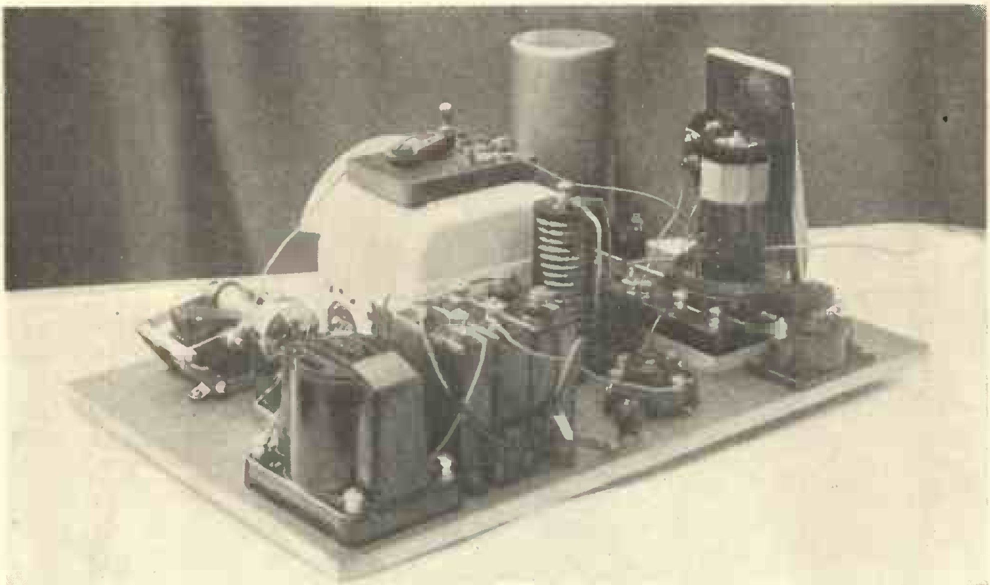


Fig. 15.—ANOTHER VIEW OF THE WIRING.

V2 to earthing screw (E, Fig. 13) on "Unitune" and to terminal No. 2 on each coil.

(8) Connect together one terminal on 2 mfd. and ¼ mfd. fixed condensers and thence to L.T. negative terminal of V3 and to P on L.F. transformer.

(9) Free terminal of midget choke to 1 mfd. condenser.

(10) Grid of V3 to G on L.F. transformer. Free terminal of first H.F. choke to 2 mfd. condenser.

(11) Connect moving plates of reaction condenser to No. 1 of the two-way switch. Connect No. 2 of switch to No. 6 on grid coil; No. 3 of switch to No. 6 on aerial coil.

Fig. 16.—CONNECTING THE TERMINAL STRIPS. The wires are put through holes in the cabinet, fixed to the sockets with screws and the terminal strip then refixed.

(12) Connect 25,000 ohm spaghetti resistance between H.T. + 3 terminal and the terminal on 1 mfd. condenser to which lead to H.F. choke is attached. Connect other terminal of same condenser to H.T. on L.F. transformer.

Battery Cord Connections

Fix a "wander-fuse" in place of the wander plug marked H.T. —. Then connect by colour as follows:—

BLUE.—H.T. negative; L.T. negative.

RED.—L.T. + on L.T. battery to terminal at free end of grid leak to which wire No. 5 of switch is attached.

WHITE.—H.T. + 1 to plate terminal of V1 and 70 volts H.T.

YELLOW.—H.T. + 2 to 110 volts H.T. and 2 mfd. condenser.

BROWN.—H.T. + 3 to baseboard terminal to which spaghetti resistance is connected and to 100 volts H.T. or as found by trial.

BLACK.—G.B. – , to G.B. battery 4½ volts negative and to G.B. terminal on L.T. transformer.

Note that the Drydex battery, No. H1038 comprises a built-in grid bias battery, hence the G.B. + wander plug on battery cord is not required unless a separate G.B. battery is used. To guard against possible short-circuits insulate the plug with tape or a rubber band wound tightly around it.

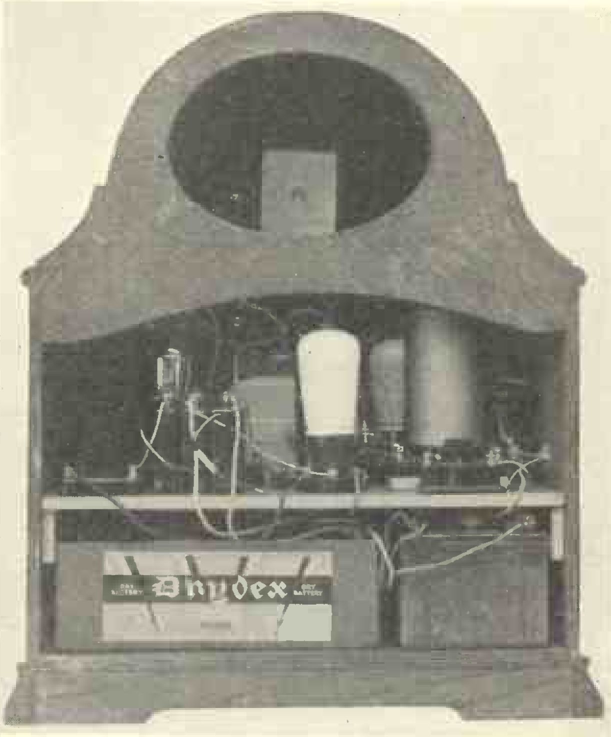


Fig. 17.—BACK VIEW OF SET.

Note the compact manner in which the batteries are fitted beneath the baseboard and how the loud speaker is kept clear of interfering parts.

Check and Inspect Wiring

Check over all connections and compare same with circuit diagram, then fit the remaining wires as follows.

Flexible wire from "Common" terminal on loud speaker to H.T. + 2 terminal on 2 mfd. condenser. Connect "Power" terminal of L.S. to plate of V3.

Connect flexible wires from Lewcodenser to aerial. From earth screw of "Unitune" to earth; from No. 3 of "on-off switch" to "pick-up," leaving sufficient length on each to pass through the holes in the cabinet.

Place the baseboard into the case, removing the coil shields to allow it to clear the back of cabinet. Replace the shields and connect the flexible wires to loud speaker and terminal strips. To do the latter remove the strips, put the wires through the holes in the cabinet and draw them tight, cut off to suitable length and connect to plug sockets, as shown in Fig. 16, push the strips back into place and refix them. Connect the second pick-up socket to G.B. negative 1½ volts when needed.

Completing and Testing

Fix the control knobs, put switch to "off" position, insert valves into their holders, then complete the connections to the batteries which, as shown in Fig. 17, fit into the compartment beneath the baseboard.

Connect to aerial and earth, put "Unitune" condenser to about 90 on dial, set reaction condenser to zero (plates fully disengaged), turn reaction switch to No. 2 and turn knob of coil switch to medium waves and screw Lewcodenser down.

Switch on, and the set should at once commence playing if a programme is being transmitted; it may, however, appear unstable because the ganged condenser has yet to be trimmed or balanced.

Balancing the Condensers

The small knob on the "Unitune" con

trols a trimming condenser, and this should be set at its middle point, next tune-in a station at medium strength at about 90 degrees on the dial, then carefully adjust the star wheel on the side of the condenser until maximum signal strength is attained, making any minor adjustments to the tuning by turning the large knob. Now turn the small central knob first one way then the other and see if increased signal strength results. If improved by an anti-clockwise movement, screw up the trimmer star wheel, or *vice versâ*.

Adjust the selectivity by unscrewing the Lewcodenser, the more it is unscrewed the sharper the tuning and the less the signal strength, consequently find by trial the best compromise between the two, then leave this condenser set and retrim the "Unitune" condenser. Wonderful results are obtained by properly trimming the condenser.

All ordinary tuning can be done with the central knob but final touches can be imparted by careful adjustment of the small central knob, and of the reaction condenser, using reaction on the aerial coil for distant stations and on the grid coil for maximum volume.

Alternative Connections

Several alternative connections can be made by those who care to experiment. For example, disconnect Lewcodenser from No. 1 of aerial coil and connect it to No. 4 of aerial coil; this gives an aperiodic aerial coupling. When this is used, best results will be obtained by disconnecting the wire between No. 1 of grid coil and ·0001 coupling condenser and connecting it to No. 4 of grid coil.

Some of these changes may be beneficial under certain conditions of reception, but normally the best results are ensured by adhering to the circuit of Fig. 14, and as described in this article. A calibration chart is hardly necessary because stations come in freely and easily all round the dial, and are no trouble to tune, when the condenser has been properly trimmed.

Optional Reaction

The facility with which the user is able to operate the "Dual Purpose Three," either with reaction on the tuned grid circuit, on the aerial circuit or without reaction, is an attractive feature that enables the very finest results to be obtained under all conditions of reception.

To obtain the very best results, however, it is desirable to select the reaction system most suited to the purpose, and with some regard to the adjustment of the pre-set aerial condenser.

In general, the local station can best be received without any reaction, but if there is a troublesome background of interference under these conditions, a remarkable improvement will be obtained by screwing down the pre-set aerial condenser a few turns and then using strong reaction on the aerial circuit.

Tune the set very carefully. It will now be much sharper than before, and will be found very sensitive to fine adjustment of the reaction condenser, for which reason the use of the slow-motion condenser more than justifies itself.

When reaction is used on the grid circuit the best results will normally be obtained by slackening the pre-set aerial condenser.

One point to note is that the dial reading varies slightly when the reaction is on the aerial to the reading when using reaction on the grid circuit.

Another most important point is that, as reaction is increased to the verge of the oscillation point, the set becomes extremely sensitive, and very fine tuning, especially with the small trimming condenser (central knob on set) is essential.

The results that can be obtained fully justify a little fine tuning, to bring in the more elusive foreign stations. All the more powerful stations come in easily with the single knob tuning.

THE BEST ARRANGEMENT OF COMPONENTS

By EDWARD W. HOBBS, A.I.N.A.

EXPERIENCED amateur constructors are aware that the manner in which the components of any given set are arranged has a profound effect on the stability or otherwise of the receiver, and the ease with which it can be handled.

Layout and Wiring

The layout or arrangement of the parts is vitally important because it determines the natural paths of the wires, hence the length and complexity of the wiring.

Secondly, the layout governs the degree of interaction between the components, and these two factors may combine to create a condition of instability—or perhaps the reverse—a "bucking" or anti-reaction effect.

A third factor must be borne in mind, and that is stray "pick-up," particularly when several stages of high-frequency amplification are employed.

Materialising a Circuit

The theoretical circuit diagram itself has little direct bearing on the problems of translating the circuit into terms of actual components and putting them in their best relative positions, hence skill and common sense should be fully exercised to ensure success.

To get away from generalities and come down to concrete example, consider a three-valve set with an H.F. valve, detector and one L.F. stage, with a built-in loud speaker.

The theoretical circuit will look something like that of Fig. 1, and this may usefully be analysed either mentally or pictorially into its three distinctive circuits, disregarding such details as decoupling devices and so forth.

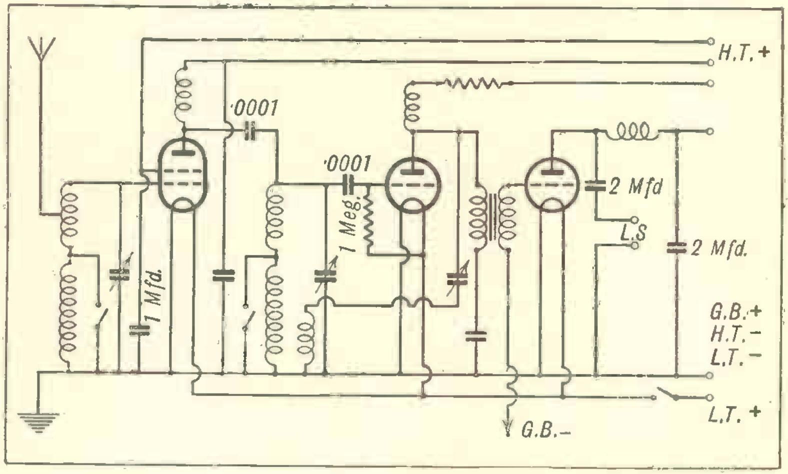


Fig. 1.—A THREE-VALVE CIRCUIT.

This circuit is given as an example to illustrate how the actual arrangement of the components themselves can make or mar the performance.

Pictorial Analysis

These three circuits are respectively the high-frequency circuit—from aerial to detector, the audio-frequency circuits from detector to loud speaker, and, lastly, the filament heating and H.T. battery circuits. In Fig. 2 these circuits are outlined as follows: high-frequency circuit, thick black lines; the audio-frequency by dotted lines, and the filament circuit by fine lines. Doing this at the start will indicate various danger points for detailed consideration.

The Danger Points

Danger points can be grouped into three heads, first direct pick-up, that is, any wires or components acting like an aerial and picking up unwanted signals.

Secondly, capacity and electro-magnetic interaction; thirdly, feed-back—or the leakage of currents from part of a circuit to another—not the ordinary H.T. or L.T. current—which would merely be a short circuit—but the leakage of high-frequency currents, causing oscillation, "motor-boating," negative reaction and other objectionable happenings.

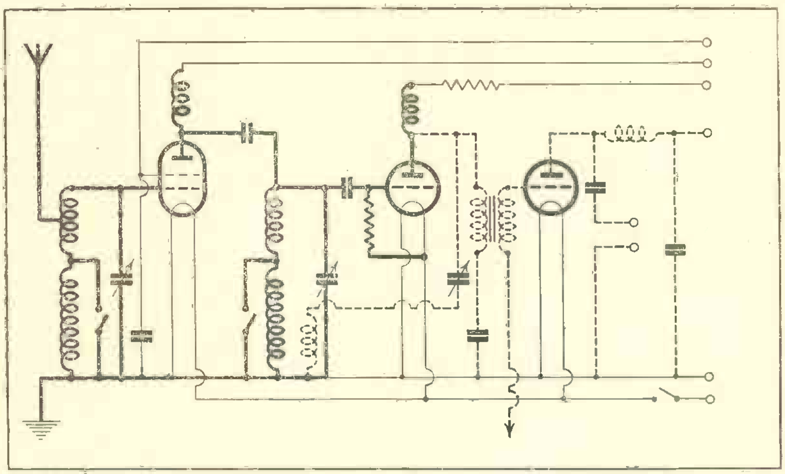


Fig. 2.—Simplified Circuit Analysed.

This simplified circuit corresponds with the previous diagram, but the high frequency circuits are outlined in heavy black, the audio-frequency circuits are dotted and the L.T. filament and H.T. battery circuits in fine lines.

Avoiding Stray Pick-up

To reduce pick-up to a minimum, use shielded coils, shielded condensers, keep all aerial leads short, all connections to tuning coils as short as possible and protect them so far as practicable by shielding, either by running them under a metallic baseboard, or by the use of metallic braiding over the wire, the braid subsequently being earthed.

Stray pick-up is more likely to be experienced when several H.F. stages are used with unshielded coils; practically speaking, the one great cure is adequate shielding.

Capacitative Interaction

The reduction of all capacitative losses is one of the most important items of receiver construction, and the effects when experienced are often very difficult to localise and remedy.

Consider for a moment what capacity interaction is and what are predisposing causes. Briefly, any wire or component carrying high-frequency currents sets up an electro-magnetic field around it—which, of course, is a loss of energy and also a means of coupling.

Any wires carrying high-frequency current are therefore of the nature of a capacity, and will in fact have a condenser effect if they run near to any metallic object at a lower potential. They have a tendency to discharge to the lower potential—in other words, they leak or interact.

In this respect the audio-frequencies must be thought of as high-frequency currents, although not so serious in effect.

H.F. Leads should be Short

All H.F. leads should be as short as practicable, generally go straight from point to point, and should be as widely spaced as possible. They ought not to run parallel to other wires, nor to objects at earth potential, nor close to any component with a radiated or external magnetic field.

Perhaps the most important item is to space the wires as widely apart as possible and have them cross other wires at right angles.

Should anyone be disposed to think the loss from capacitative interaction is over-stressed, just examine a ·0005 bakelite dielectric variable condenser; this has very little metal in it, but its effect in a tuning circuit is very marked.

The total H.F. wiring in a set has much more metal in it than there is in the condenser, hence the dangers from stray capacities and interaction can be very serious.

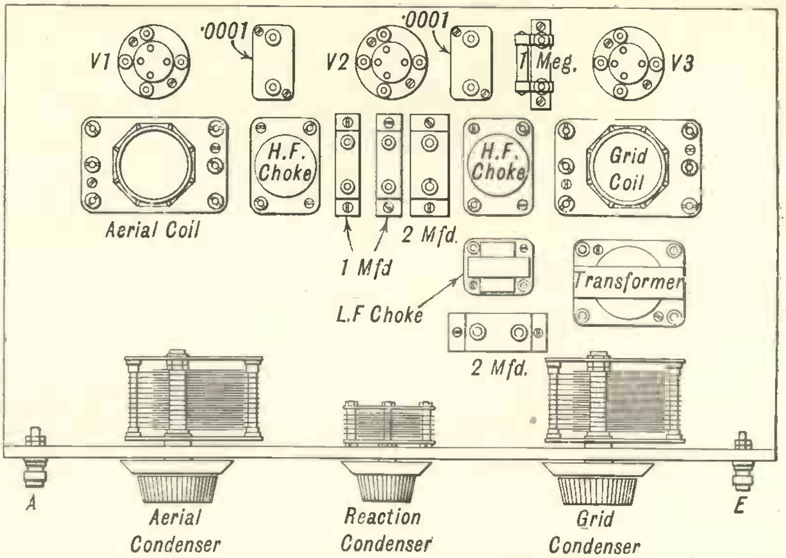


Fig. 3.—Bad Arrangement of Components.
Here the components are badly spaced and necessitate long parallel leads.

Magnetic Interference

A metal-framed reaction condenser in the anode lead of the detector circuit to a reaction coil and thence to earth, necessarily has all parts of the condenser charged with high-frequency currents, consequently if it is placed anywhere near a metallic object there must be interaction between them. If the independent object is earthed, there is a chance that the set will be unstable because of continuous reaction, the charged frame of the condenser acting in the same way as would the plates to feed current *viâ* the general earth return to the reaction coil.

If the nearby object has a magnetic field it may interact with the condenser and either prevent proper reaction, or may feed into the reaction circuit.

Obvious remedies are to place the condenser where it cannot be so affected or to use a fully insulated metallic shield, or to put the condenser on the earth side of

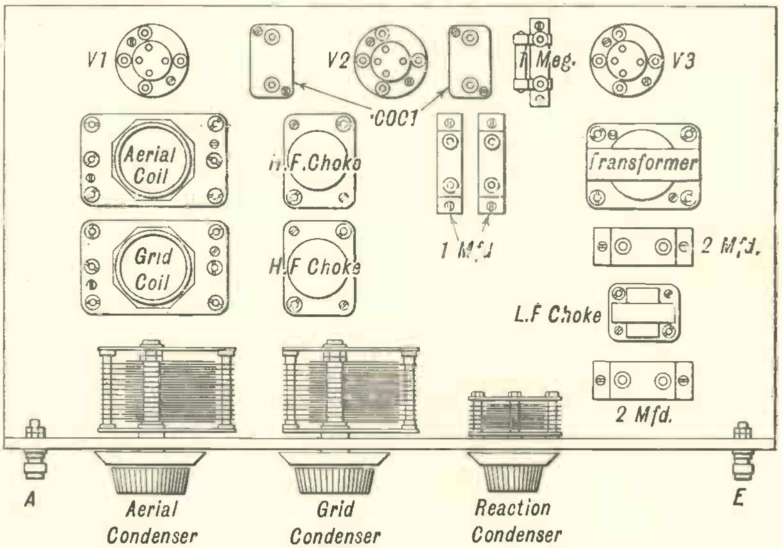


Fig. 4.—Concentration of Coils and Condensers.
This arrangement is preferable to that of Fig. 3, but the condensers are too close and the detector is remote from grid coil, necessitating long grid leads.

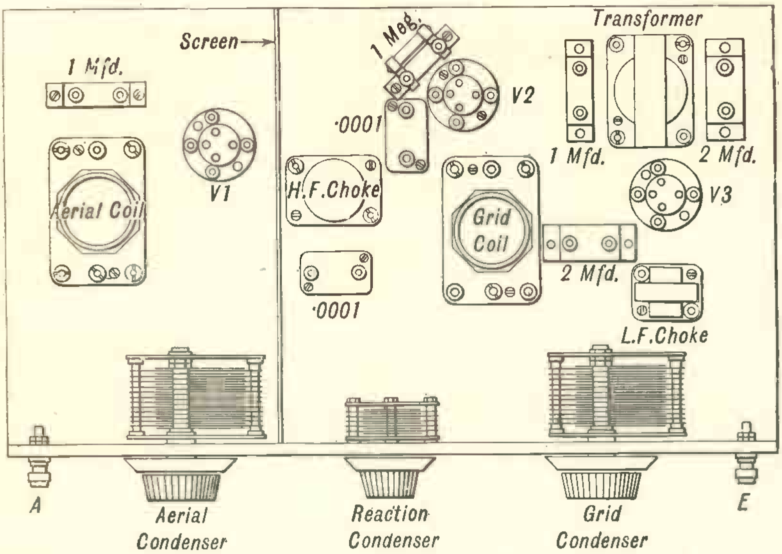


Fig. 5.—Best Arrangement of Components.

The various components are grouped according to their circuits, arranged in natural sequence, enabling short well-spaced wiring.

the reaction coil, and always to use short separate earth return wires to the filament of the valve concerned or direct to earth as the case may be.

Decoupling

Feed back is rather different to direct interaction because it means that a current flow on the H.F. side is inducing another current flow on the audio-frequency side of the circuit. For example, if a wire or component carrying H.F. current runs too near one in the audio-frequency side, some of the unrectified current may leak into the audio-frequency leads, pass through the loud speaker and find its way back to the aerial circuit and there set up oscillations which repeat the process and become audible as a shriek or whistle. The remedy is adequate and direct decoupling—the use of by-pass condensers to afford a direct easy return path for unwanted currents to earth or to the negative filament terminal of the appropriate valve. Resistances in the leads to be protected are necessary, and their H.F. resistance should generally be about ten times that of the by-pass circuit.

Placing the Actual Components

Three alternative practical arrangements are shown in Figs. 3, 4, 5; the first is very bad and would necessitate long parallel leads, the arrangement in Fig. 4 is better, but the coils and condensers are too close, in Fig. 5 the H.F. valve is fully shielded, the leads are as short as practicable and the components well spaced and arranged in their natural sequence. In all three examples the same components are used. The L.T. battery leads seldom give trouble so long as an independent earth return is provided.

Composite Components

Modern commercial practice indicates a growing tendency to incorporate several components into one compact unit, a practice that is to be commended, as it reduces the number of wires and generally makes possible the housing of several cognate components in one compact shielded unit.

Formo Multicoupler

A case in point is the "Formo Multicoupler," a small nickel alloy transformer mounted in a double screen to prevent electro-static and electro-magnetic interaction, together with alternative feed resistances and condenser. Eight terminals on the base enable choice of three transformer ratios and various ways of connecting the resistances for parallel feed, and for decoupling.

How the Efficiency of the Set is Improved

The use of any such components definitely aid the efficiency of a set by reducing extraneous losses to a minimum.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XI—WIRELESS WAVES AND TUNING CIRCUITS

FROM the preceding sections we have learned two important facts. Under certain conditions rapidly moving electrons will cause an electro-magnetic wave in the ether and an electro-magnetic wave, in its turn, will cause electrons to move in a conductor.

We have defined a condenser as two conducting plates separated by a dielectric. An aerial wire and a counterpoise (another wire or a number of wires placed directly under the aerial and insulated from earth) will also form a condenser, as here again we have two conductors separated by air. In order to make our present investigation as simple as possible let us consider such a system with an alternator in between, as shown in Fig. 1, as a source of alternating E.M.F. Let us start once more when the system is uncharged and there is no electric field between the two "plates" of our condenser and no magnetic field around the conductors, as there is no current flowing in the circuit.

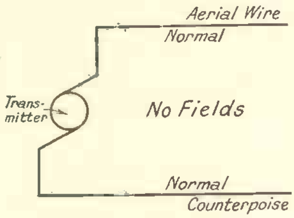


Fig. 1.—THE SYSTEM UNCHARGED.

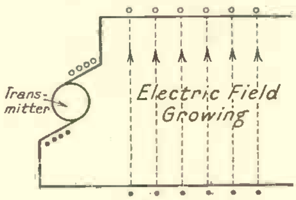


Fig. 2.—ELECTRIC FIELD GROWING.

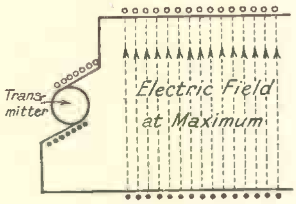


Fig. 3.—ELECTRIC FIELD AT MAXIMUM.

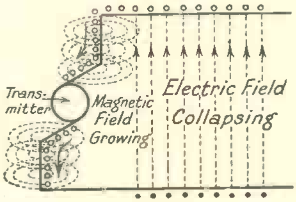


Fig. 4.—ELECTRIC FIELD COLLAPSING AND MAGNETIC FIELD GROWING.

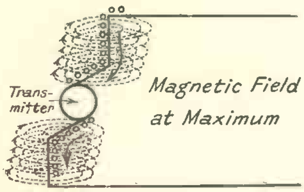


Fig. 5.—ELECTRIC FIELD, ZERO; MAGNETIC FIELD, MAXIMUM.

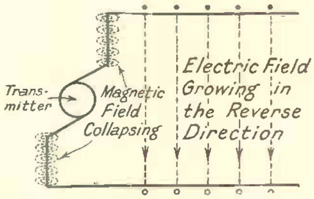


Fig. 6.—REVERSED ELECTRIC FIELD; MAGNETIC FIELD COLLAPSING.

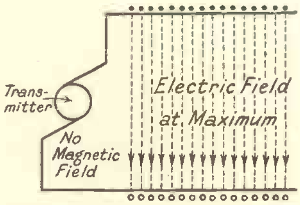


Fig. 7.—REVERSED ELECTRIC FIELD, MAXIMUM; MAGNETIC FIELD, ZERO.

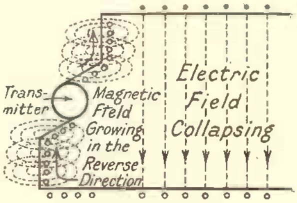


Fig. 8.—ELECTRIC FIELD COLLAPSING, MAGNETIC FIELD GROWING IN REVERSE DIRECTION.

How the Electric Field Grows and Diminishes

We now know from the previous analysis that as the cycle of events progresses, charging and discharging of the system will take place, and at various definite and always recurring intervals of time we shall have the electric field growing from zero to a maximum (Figs. 2 and 3). As soon as the electric field has reached its maximum (the whole system is now fully charged) the alternator E.M.F. will start to diminish, a gradual increase in strength of electronic tide will take place (a discharge current will begin to flow), and for this reason the electric field will commence to collapse, and the magnetic field around the conductors will begin to grow with the gradually increasing current.

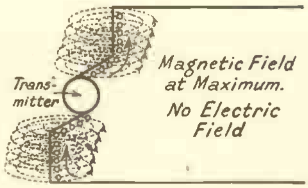


Fig. 9.—ELECTRIC FIELD, ZERO; MAGNETIC FIELD AT MAXIMUM.

Magnetic Field Grows as Electric Field Collapses

Thus, in Fig. 4, we see the moment when the electric field is collapsing and the magnetic field is growing. In Fig. 5 we have a maximum magnetic field and the electric field at zero. The system is now being charged in the opposite direction, so that we have a reversed electric field growing once more (Fig. 6) and the magnetic field collapsing.

In Fig. 7 the reversed electric field is at a maximum and there is no magnetic field. The system is now fully charged in the reverse direction. After this the electric field is collapsing once more and the magnetic field is growing.

Now imagine this happening a million times a second. You will realise that such drastic changes in the state of the ether occurring at such a tremendous rate are bound to produce a disturbance of a considerable extent.

Why the Earth behaves as a Conductor

If the counterpoise is connected to earth, as shown in Fig. 10, the effect is the same as before, so that we can dispense with the counterpoise altogether and use the earth as the second plate of our condenser. The reason for this is that the earth is a conductor, or, rather, behaves as a conductor. Consider Fig. 11, in which is shown a cell connected to earth at both terminals. Electrons will flow from the negative terminal to earth, as we have learned from electrostatics, and at the same time electrons will flow from earth to the positive terminal of the cell. The final result is the same as if electrons were flowing all round the circuit, while the chemical reactions inside the cell maintain a difference of electrons per atom between the two terminals of the cell.

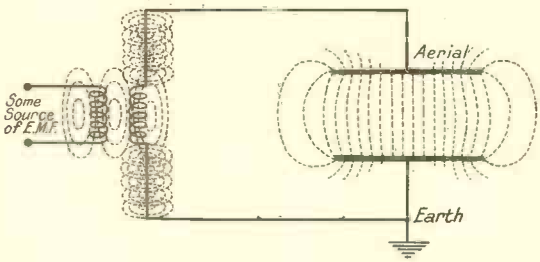


Fig. 10.—SHOWING HOW THE EARTH BEHAVES AS A CONDUCTOR

Area over which Electric and Magnetic Fields are Out of Step

When a source of radiation such as a broadcasting station is made to produce a disturbance in the ether, such as described above and illustrated in Figs. 1 to 9, it is found that within the quarter of the wavelength (if the wavelength is 200 metres, within the distance of 200/4 or 50 metres) from the radiating or transmitting aerial the electric and the magnetic fields are out of step or phase, to use an engineering expression, so that when the electric field is at maximum the magnetic field is zero and *vice versâ*, with all the gradual changes in between.

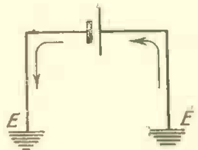


Fig. 11.—A CELL CONNECTED TO EARTH AT BOTH TERMINALS.

Difference between Open and Frame Aerials

But beyond this quarter of the wavelength the two fields fall into step, start changing in intensity and direction simultaneously, and, having achieved this, dart off into space with a

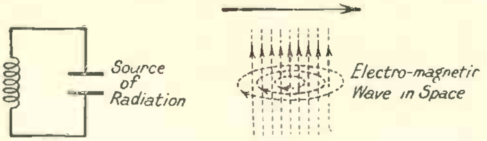


Fig. 12.—Electro-Magnetic Wave in Space Going Away from a Radiating System.

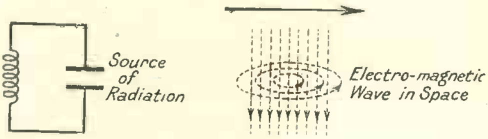


Fig. 13.—Electro-magnetic Wave in Space. Showing field in opposite direction to Fig. 12.

speed of 186,000 miles per second. When thus flying in space they grow and diminish together, when one disappears the other disappears, when one is at a maximum the other is at a maximum, and so on. When they arrive near a receiving aerial it is the electric field that acts on an open aerial-earth system (forming a condenser) causing electronic tides in the aerial, and it is the magnetic field that acts on a closed aerial system such as a frame aerial inducing in it an E.M.F. in the ordinary way when lines of magnetic force cut the conductors of a closed system at right angles.

How the Lines of Force Travel

Unless the electro-magnetic wave is specially oriented by the transmitting aerial, the lines of force of the electric field are vertical when travelling in space, and the lines of force of the magnetic field are horizontal. Figs. 12 and 13 show an electro-magnetic wave in space going away from a radiating system, two instants being shown in which the fields are in the opposite directions. It is generally assumed that when the lines of force of the electric field are travelling in space, they travel in the form of loops, as shown in Fig. 14. The isolated lines are sort of bending upon themselves.

The Heaviside Layer

It is easily realised that with an elevated aerial wire, while the electrons within the atoms of the wire are darting to and fro, the ether is equally disturbed in all directions so that a normal radiating system will send out waves in all directions. Some of the waves are thus made to travel along the surface of the earth and are known as ground waves. Some go into upper direction away from the surface of the earth. Some sixty miles above the earth's surface there is a belt of ionised atoms, and even free electrons, which form a sort of spherical " blanket " all round the earth. This is known as the Heaviside layer. Its function is to reflect wireless waves back to earth. Longer waves suffer greater reflection than short waves, and apparently very short electro-magnetic waves such as heat, light, ultra-violet rays, etc., are capable of penetrating the Heaviside layer without being reflected.

The Appleton Layer

Beyond the Heaviside layer is another layer, now called the Appleton layer (after Professor Appleton), which behaves in a similar manner. These layers give rise to what is known as wireless echoes. Research has shown that a signal sent out into space can be received several times. The repetition of the signal is due first of all to the wave going round the earth in opposite directions and meeting at the receiving aerial, the second wave arriving a little later than the first; secondly it is due to the reflection from the Appleton layer.

Limit of Range of a Broadcasting Station

It is clear that since an electro-magnetic wave is capable of moving electrons in a

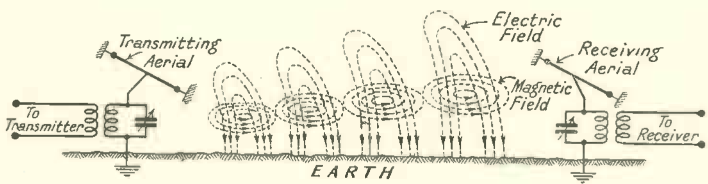


Fig. 14.—Showing how the Lines of Force are Generally Assumed to Travel.

conductor, in doing so it must expend a certain amount of work, *i.e.*, it must dissipate some of its energy. Generally speaking, the farther afield from the transmitting station the weaker the wave and therefore the weaker the signal. This limits the range of a broadcasting station. The Admiralty Handbook for 1931 gives the following ranges for a station having a range of 1,000 miles over an *ideal* conducting surface. (The better the conducting surface over which the wave passes the less energy it will dissipate in moving electrons about.)

Across sea	920 miles
Across fresh water or bog	700 ,,
Across wet soil	560 ,,
Across damp soil	270 ,,
Across dry soil	150 ,,
Across very dry soil	55 ,,

The smaller the wave-length of the wireless wave the greater the loss of energy over a conducting surface, as the more frequently the electrons in the conductor have to be moved about.

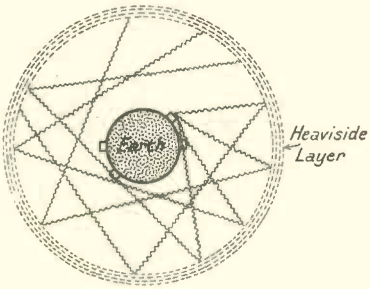


Fig. 15.—This shows Roughly how Wireless Waves are Reflected from the Heaviside Layer.

Effect of Electric Field of Electro-magnetic Wave on Outdoor or Indoor Aerials

Both the outdoor and the indoor aerials are influenced by the electric field of the electro-magnetic wave, which, in varying in intensity and reversing its direction, acts upon the electric field surrounding the electrons, either repels or attracts them, and so causes the electrons to move.

What Happens in the case of a Frame Aerial

In the case of a frame aerial it is the magnetic field of the electro-magnetic wave that acts on the magnetic fields around the electrons moving in their atomic orbits, and by either attracting or repelling them causes the electrons to move from atom to atom. This fact is an old acquaintance, as we already know that the lines of force of a magnetic field cutting the conductor of a closed loop will induce an E.M.F. across it, and thus cause an electric current to flow in it. Since the " cutting " must be done at right angles this implies a definite directional effect on the aerial.

Why a Frame Aerial is Directional

As far as the electric fields are concerned they have a certain directional effect as well, so that an ordinary outdoor aerial receives much better in one direction than another, but, as a rule, this effect is not so pronounced as in the case of a frame aerial. When the alternating magnetic field arrives from a station which is in the same vertical plane as the frame, the field will cut first the conductors on one side of the frame then the conductors on the other side of the frame. Thus a certain interval of time will elapse between the two cuts. But, since the magnetic field is varying in intensity with great rapidity, its intensity will not be the same at each cut. This means that if the wave is arriving from such a station it will first cut the nearer side of the frame, and then when its intensity is, say, somewhat diminished, the far side of the frame. In this way the E.M.F. induced during each cut will be different and the resultant E.M.F. will be the difference between the two.

When the wave arrives from a station not in this vertical plane, its field will cut the two sides at a much shorter interval, owing to its position, than the interval in the case of the first station. For this reason the difference in phase between the two E.M.F.s will be smaller and the resultant E.M.F. will be smaller. Therefore the signal will be weaker.

When no Signal will be Received

If the station is 90° off the plane of the frame the wave will strike both sides of the frame simultaneously, the two induced E.M.F.'s will be equal and opposite, and the difference between them will be zero. There will be no signal at all.

As you see in each case the horizontal lines of force of the magnetic field of the arriving wave cut the conductors of the frame aerial at right angles, but they do not cut both sides of the frame at the same time when the station is not in a plane parallel to the frame. The small interval of time between the cut allows the wave to change its intensity, so that the E.M.F. induced in each side is not the same and the resultant E.M.F. is the difference between the two. With a simultaneous cut the final E.M.F. is zero, as each cut induces an equal and opposite E.M.F.

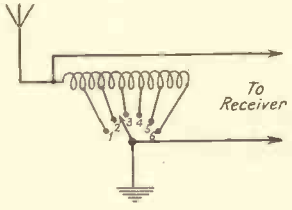


Fig. 16.—VERY OLD METHOD OF TUNING BY MEANS OF A LONG TAPPED COIL.

The Natural Wavelength of an Aerial

When we erect an aerial with its lead-in wire and fix our earth lead we already have in our aerial-earth system a certain amount of inductance and capacity, apart from the coils and condensers we may be using in this circuit. This inductance and capacity will determine a fundamental wavelength or, as it is often called, the *natural wavelength* of our aerial below which we cannot go unless we cut down the length of wire in the aerial.

If the natural wavelength of our aerial is, say, 300 metres, we cannot receive any station working below this wavelength.

THE TUNING CIRCUIT

The official journal of the B.B.C., *World Radio*, gives 216 broadcasting stations working within the range of wavelengths of 1,935 metres and 208·7 metres and another 100 short-wave stations ranging from 80 metres to 13·92 metres.

A large number of these stations are working simultaneously, so that the listener unless he can pick out any particular station, cannot listen at all.

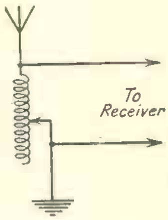


Fig. 17.—TUNING BY MEANS OF A SLIDER.

How Wavelength of a Station is Determined.

The wavelength of a station is determined by the amount of inductance and capacity in the aerial circuit. It is directly proportional to the product of these two quantities.

Wavelength is proportional to inductance × capacity

This means that if we increase the inductance of the aerial circuit with a given definite capacity, or if we increase the capacity while the inductance remains constant, we shall increase the wavelength. In other words, if we vary either the inductance or the capacity we shall vary the wavelength.

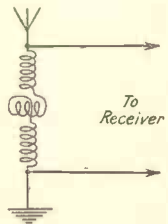


Fig. 18.—VARIOMETER TUNING.

How the Natural Wavelength may be Altered

If we make the aerial shorter we may drop this natural wavelength, or we can connect a condenser in series with the aerial and thus drop its total capacity (two capacities in series give a resultant capacity which is smaller than any of the two individual capacities) and thus drop the natural wavelength of our aerial-earth system.

Adjusting the Aerial-earth System to a given Wavelength

Since we already know that wavelength is inversely proportional to the frequency, in adjusting our aerial-earth system to a given wavelength we determine the frequency at which the electrons in the aerial will oscillate with the greatest of ease, or, in other words, we fix the electrical constants of our aerial - earth system so that it will offer the least possible opposition to an incoming electric field and give it every facility to move the electrons in the aerial at its own frequency.

Getting Rid of Undesired Wavelengths

In the same manner, if we want

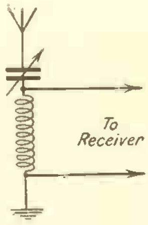


Fig. 19.—Acceptor Circuit.

to get rid of some undesired wavelength we can adjust our aerial in such a way that it will offer a tremendous amount of opposition to that particular wavelength while offering little opposition to all other wavelengths. This question we shall consider a little later, but in the meantime let us survey the more common methods of varying the inductance or the capacity of our aerial-earth system.

Tuning by Means of a Long Tapped Coil

In Fig. 16 we have a very old method of tuning by means of a long coil tapped at a large number of points, each tapping brought to a stud, each of which can be connected to the rest of the circuit by means of the movable arm of the switch. The inductance of a coil depends, amongst other things, on the number of turns in the coil. The more turns there are, the greater the inductance. Since one end of the coil is connected to the aerial and the arm of the switch is connected to earth, the inductance of the aerial circuit will vary as the arm is moved from stud to stud, *i.e.*, as the number of turns between the aerial and earth is being varied. The drawback with such a coil is that there is often a portion of the coil remaining inactive, a "dead end" is left, and the effect of the "dead end" is to reduce the efficiency of tuning. This is known as the "dead end" effect.

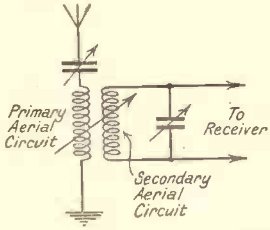


Fig. 21.—Loosely Coupled Aerial System.

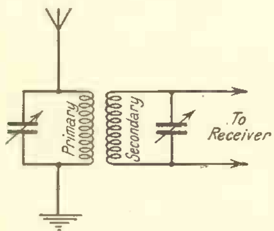


Fig. 22.—A Rejector Circuit Loosely Coupled to Another Rejector Circuit.

Tuning by Means of a Slider

In Fig. 17 we have a similar coil, but in this case, instead of having tappings, a slight saw cut is made along the whole length of the coil so that we have a line of bare wire, the saw removing a small portion of the insulation, and thus each turn can be in contact with a sliding metallic point. While in the previous case, in going from stud to stud we have jumped a few turns at a time, in this case we are sliding smoothly from turn to turn. The method of tuning shown in Fig. 17 is more delicate and continuous than in the case of Fig. 16.

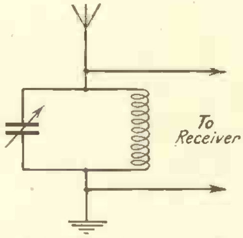


Fig. 20.—Rejector Circuit.

Variometer Tuning

In Fig. 18 a variometer method of tuning is shown. A variometer consists of two coils, of which one is a comparatively large outer cylindrical coil and the other a small inner cylindrical coil or a round coil wound on a spherical former. The small coil is inside the large coil and is capable of rotating around its own axis. The two coils are connected in series. In rotating the inner coil we alter the sense of its winding and therefore we alter the direction of the magnetic field around it. When the directions of the outer and the inner magnetic fields coincide we have a large combined field and thus have a large number of lines of force linking with the turns of the coils. A large number of such linkages means a large inductance. If the direction of the lines of force of the two fields is in opposition the resultant field is the difference of the two, there are fewer lines of force, and therefore there are fewer linkages and the inductance of the system is small, or zero.

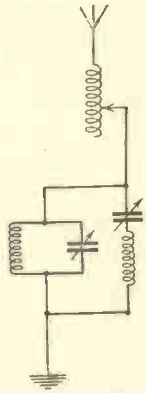


Fig. 23.—A Rejector Circuit Connected in Parallel with an Acceptor Circuit.

Another Method of obtaining the same Result

A similar result can be achieved by joining in series two flat coils and make them slide on top of each other. Such a method has been used in the past in the case of the "Radiocraft" (C. F. Elwell Ltd.) crystal set.

You will notice that up to the present we have been varying the inductance only. Now we come to methods which enable us to vary the capacity of the circuit with a given inductance.

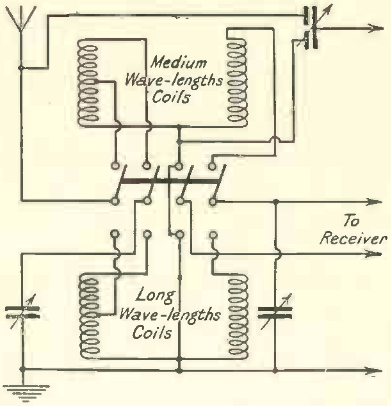


Fig. 24.—Circuit for Reducing the Number of Tuning Controls.

Acceptor and Rejector Circuit

In Fig. 19 we have the so-called *acceptor circuit*, which consists of a variable condenser and a coil in series with the aerial. As the overlap between the vanes of the condenser is varied, the capacity of the condenser is varied and, therefore, the capacity of the aerial circuit as a whole is varied. We shall devote a good deal of space to this circuit here as well as to its opposite number, called the *rejector circuit*, shown in Fig. 20. The rejector circuit, as you can see, consists of a variable condenser in parallel with a coil, the whole combination being placed between the aerial and the earth.

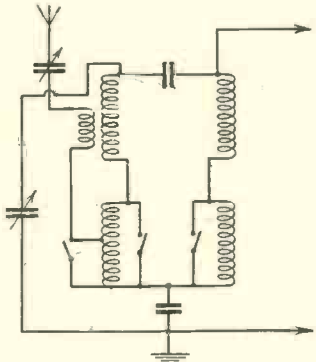


Fig. 25.—Band-Pass Tuning Circuit.

These two circuits are the fundamental tuning circuits and are highly important in the design of wireless receivers.

In the case of the acceptor and the rejector circuits it is possible to extend the range of wavelengths with which the system can deal by using plug-in coils, so that, in addition to the variation of capacity, we can also vary in large steps the amount of inductance available.

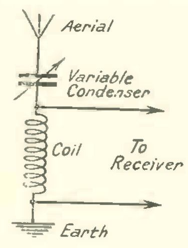


Fig. 26.—General Form of Acceptor Circuit.

Loosely Coupled Aerial System

In Fig. 21 we have what is called a loosely coupled aerial system of which the primary circuit consists of an acceptor circuit and the secondary of a rejector circuit. But it should be noted that in this case the rejector circuit does not behave as a true rejector circuit owing to modification of conditions in which it is used as compared with Fig. 20.

Two Rejector Circuits loosely Coupled

In Fig. 22 we have a rejector circuit loosely coupled to another rejector circuit.

It should be noted that both in the case of Fig. 21 and Fig. 22 we have a current flowing in the primary system (connected between the aerial and earth) a current which produces a magnetic field around the primary coil, and this magnetic field cutting the conductors or turns of the secondary coil, induces a current in it and thus electrical energy is being transferred from one circuit to another. This question of induction has already been discussed.

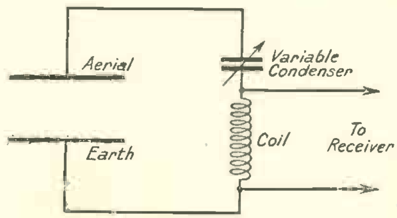


Fig. 27. — Acceptor Circuit in another Form.

What an Acceptor Circuit does

Broadly speaking, an acceptor circuit, as its name implies, will accept only one desired wavelength while rejecting all others. A rejector circuit will reject one chosen wavelength while accepting all others. For this reason combinations of the two are used in all sorts of ways, and a typical case of such a combination is shown in Fig. 23. Here a rejector circuit is connected in parallel with an acceptor circuit.

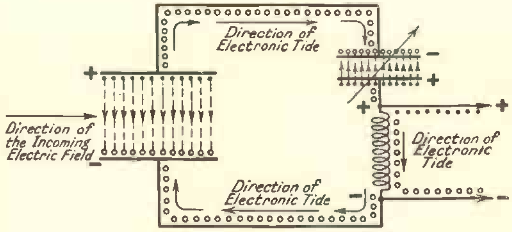


Fig. 28.—Showing what Happens when the Electric Field Arrives and Starts Charging the Aerial-Earth System by Causing Electronic Tides in the Aerial.

Reducing the Number of Tuning Controls

The modern tendency is to reduce the number of receiver controls as much as possible, and for this reason ganged condensers are used extensively, coils are connected to wave-changing switches, which switch over the aerial circuit from long to short wave coils, and the number of manipulations is thus reduced considerably. An example of such an aerial circuit is given in Fig. 24.

Band Pass Tuning

The method of *band-pass tuning*, which is discussed elsewhere in this work, is illustrated in Fig. 25.

On close analysis it will be seen that the two fundamental circuits, *i.e.*, the acceptor and the rejector circuits, are incorporated in every method of tuning, and it is therefore essential to understand their action if the general idea of tuning is to be grasped at all. In this article we are not concerned so much with the application of the various methods of tuning (this has been and will be discussed elsewhere in this work) as with the fundamental principles underlying all tuning.

Fundamental Principles of the Acceptor Circuit

Let us consider the acceptor circuit first. In Fig. 26 we have the general form of the acceptor circuit. As we have already discovered, the aerial and the earth are equivalent to the plates of a condenser, as the electric incoming field of the electromagnetic wave radiated from a broadcasting station establishes itself and alternates between the aerial and earth as it would establish itself and alternate between the plates of a condenser. For this reason we can re-draw Fig. 26 as Fig. 27.

Accumulation of Electrons in the Condenser

In Fig. 28 we have a state of affairs when the electric field arrives and starts charging the aerial-earth system by causing electronic tides in the aerial. Let us assume that the aerial is being made poor in electrons, *i.e.*, the electric field is repelling electrons from the aerial wire towards the upper plate of the variable condenser. The accumulation of electrons on the upper plate of the condenser will cause a repulsion of electrons from the lower plate of the variable condenser, the electronic tide flowing through the coil towards earth. The direction of this *instantaneous* electronic tide is shown clearly in Fig. 28 by means of arrows.

What happens when the Electric Field is Reversed

When the direction of the electric field is reversed and the aerial wire is made rich in electrons by attraction of electrons from the upper plate of the variable condenser, the electronic tide will be reversed, as can be seen in comparing Figs. 28 and 29. The pro-

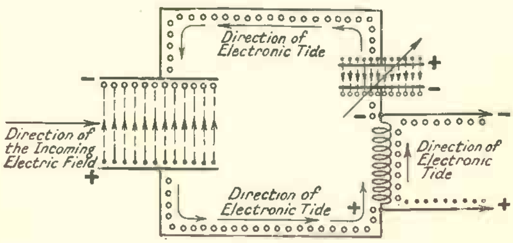


Fig. 29.—Showing what Happens when the Direction of the Electric Field is Reversed.

tons left unbalanced on the upper plate of the variable condenser (Fig. 29) will attract towards them and therefore towards the lower plate of the variable condenser the electrons from the rest of the circuit, with the result that electrons are now flowing from earth towards the coil and the lower plate. Now these two instants were depicted during the process of *charging* of the aerial, and therefore of the variable condenser.

It should be noted that at every instant what happens across the aerial and earth happens across the wires leading to the receiver. Note the signs of potential in each case.

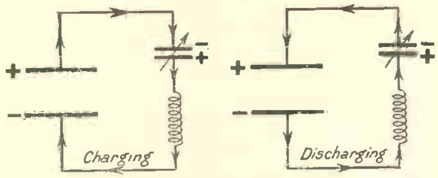


Fig. 31.—Direction of Currents during Charging and Discharging at the Instant shown in Fig. 30.

Aerial System and Variable Condenser fully Charged.

In Fig. 30 we have an instant when the aerial system and therefore the variable condenser are fully charged, the aerial being positive, the incoming electric field at the moment is zero and therefore the variable condenser, having no E.M.F. applied to it, is free to discharge at full strength. The discharge current is seen to be flowing from the upper plate of the variable condenser towards the aerial which is poor in electrons (a state of affairs which prevailed at the instant shown in Fig. 28), and from earth towards the lower plate of the variable condenser, *viâ* the coil. The direction of the currents during

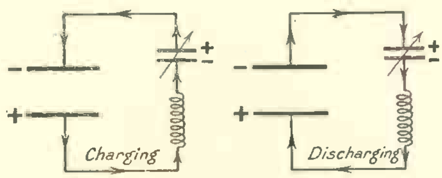


Fig. 33.—Direction of Currents During Charging and Discharging at the Instant Shown in Fig. 32.

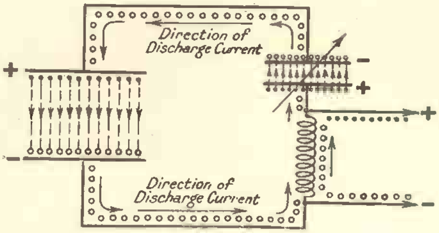


Fig. 30.—The Aerial System and Variable Condenser Fully Charged.

charging and discharging is shown in Fig. 31.

When the acquired charge is in the opposite direction the discharge current will flow from the lower plate of the variable condenser and from the aerial towards the upper plate of the variable condenser. Again, the direction of charging and discharging currents, at this particular instant, is shown in Fig. 32.

If you carry out the analysis already indicated you will see that first of all the system is charged and then as the electric field is alternating there will always be a final current flowing in the system which is at every instant the difference of the charging and the discharge currents flowing.

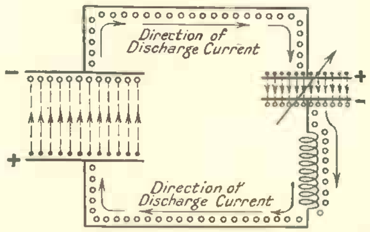


Fig. 32.—Showing the Aerial System Charged in Opposite Direction.

The Oscillating Current

Since this difference will be always varying as the applied E.M.F. varies, the applied E.M.F. due to the incoming alternating electric field, we shall always have in the circuit an alternating current flowing, which will vary in strength from instant to instant and in direction, the frequency of variation of direction depending on the frequency with which the electric field, *i.e.*, the electro-magnetic wave, varies in direction. Thus, this frequency of direction change of our current will

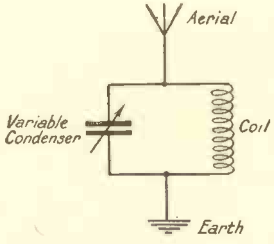


Fig. 34.—General Form of Rejector Circuit.

depend on the wavelength of the incoming wave. When this alternating current, or, as it is called, owing to the rapidity of changes of direction, *oscillating current*, is flowing through the coil, the self-inductance of this coil will come into play, and the current flowing through it will be the difference of the oscillating current and the current of self-induction. The greater this current of self induction the greater the opposition offered by the coil to the oscillating current.

Back Pressure exerted by the Condenser and the Coil

The coil "resents" any rapid changes in the strength of the current and its direction, and it will always oppose such changes. Thus, it can be seen that both the condenser and the coil exert a back pressure or a back E.M.F. always opposing

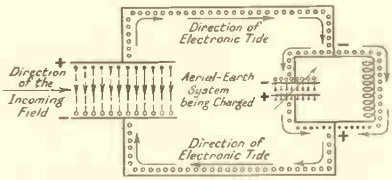


Fig. 36.—Showing What Happens When Electric Field Arrives.

that applied by the electric field E.M.F. If we adjust the value of our coil and the capacity of the condenser so that at a given frequency their back E.M.F.'s are equal, being opposite in direction to each other, they will neutralise each other and the circuit will offer the least possible opposition to changes of a given frequency, and therefore wavelength, while it will offer a much greater opposition to any other frequency (wavelength).

The current due to the selected wavelength will therefore be much stronger than those due to other wavelengths, and this strong current will produce a considerable difference of potential across the coil, and therefore the rest of the receiving circuit as compared to all other currents induced by undesired wavelengths.

What happens in the Rejector Circuit

Fig. 34 shows the rejector circuit and Fig. 35 its equivalent. In Figs. 36 and 37 we have once more the two instants of charging of the system in the reversed direction. Fig. 38 shows one instant of discharge and Fig. 39 the difference between charging and discharging when the aerial is made poor in electrons.

Fig. 40 shows the state of affairs when a negatively charged aerial is discharging, and Fig. 40 once more depicts the differ-

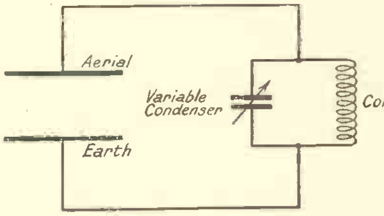


Fig. 35.—Rejector Circuit in another Form.

ence between charging and discharging when the aerial is rich in electrons.

In studying the currents flowing in the rejector circuit we see at a glance that once more we are dealing with an oscillating current which oscillates with the frequency of the incoming wave.

Again, the current flowing is the difference, at every instant, between the charging and the discharging current. Now look closely at the diagrams showing the discharging in Figs. 39 and 41.

You will see at a glance that the currents flowing between the points A and B are in the opposite direction to each other at each instant. When these currents are unequal in strength it means that there will always be a local circulating current equal to the difference of the two

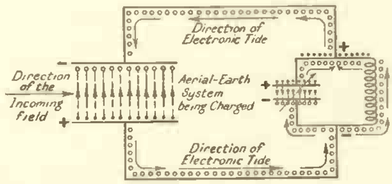


Fig. 37.—Showing Electric Field in Reverse Direction.

going from one plate of the variable condenser round the coil and back again to the other plate of the condenser.

Always a Difference of Potential

For this reason there will always be a difference of potential across the points A and B which are connected to the rest of the receiver. But if we make these two currents equal in magnitude by adjusting the opposition due to the condenser and the opposition due to the coil so as to make them equal, or, in other words, if we make the back E.M.F. of the condenser equal to the back E.M.F. of the coil, we shall have no local circulating current, and, therefore, no difference of potential across the points A and B. The rest of the circuit will get no current and no signals will be heard.

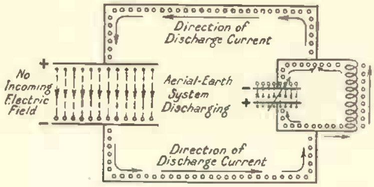


Fig. 38.—ONE INSTANT OF DISCHARGE.

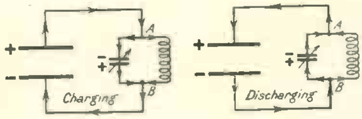


Fig. 39.—SHOWING THE DIFFERENCE BETWEEN CHARGING AND DISCHARGING WHEN AERIAL IS POOR IN ELECTRONS.

How certain Wavelengths can be Rejected

Now, the condenser can only be adjusted so that its back E.M.F. is equal to the back E.M.F. of the coil in the case of a current of a given frequency. Thus, for a wave of a certain frequency, *i.e.*, of a certain wavelength, it is possible to adjust the condenser so that the rest of the circuit gets no impression at all. This is how a certain wavelength can be rejected. For waves of other frequencies the adjustment will not hold good and their currents will go through. Thus the rejector circuit can be adjusted to reject one particular wavelength and to accept all others.

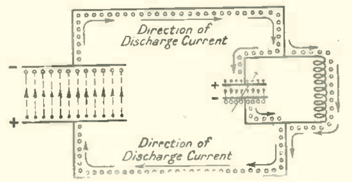


Fig. 40.—STATE OF AFFAIRS WHEN A NEGATIVELY-CHARGED AERIAL IS DISCHARGING.

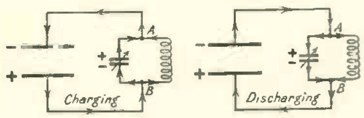


Fig. 41.—DIFFERENCE BETWEEN CHARGING AND DISCHARGING WHEN AERIAL IS RICH IN ELECTRONS.

Why a Rejector Circuit is often called a Wave-trap

In this manner, if we have a powerful station interfering with our signals we can use a rejector circuit in our aerial-earth system to *trap* the currents due to that wavelength within the local circuit consisting of a condenser and a coil in parallel and by neutralising the currents in the two branches make them cancel out each other and so make the signals inaudible. This is the reason why a rejector circuit is often referred to as a wavetrap.

Differences between Acceptor and Rejector Circuits

In comparing the acceptor and the rejector circuits we see that an acceptor circuit offers an easy path to the current induced by the wavelength to which it is tuned and a difficult path to currents induced by all other wavelengths, while the rejector circuit offers a difficult path to current induced by the wavelength to which it is tuned and an easy path to all other currents. The degree of "acceptance" by the acceptor circuit depends on the ratio $\frac{\text{inductance}}{\text{capacity}}$ or $\frac{L}{C}$. The greater this ratio the better the circuit works.

The rejector circuit should be merely used as a trap for any particular wave. When the rejector circuit is used as a secondary aerial circuit it does not behave as a true rejector circuit, its function is now merely to "pump" electrical energy from one circuit to another.

With a loosely coupled system if the signals are weak for no apparent reason, try reversing the connections of one of the coils.

SERVICING

PHILIPS 830A, 630A, SUPER INDUCTANCE RECEIVERS, NOTES ON EARLIER RECEIVERS TYPES 2531, 2534, 2514 AND 2502

Fig. 1.—MAKING A LOW VOLTAGE CIRCUIT TEST ON A PHILIPS 830A RECEIVER.
This should be carried out with a D.C. meter having a resistance of 1,000 ohms per volt together with a 4-volt battery.

General Method

THE quick location of a fault in a receiver will be determined by the method in which the tests are carried out.

Therefore, it is essential to adopt a preconceived plan, and the same method should be followed wherever possible, with all types of receivers.

Where an inspection of a receiver is carried out in the actual place in which the instrument is used, it is desirable, in the first place, to carefully examine all external connections to the receiver, including a measurement of the mains voltage. Having satisfied oneself of the good condition of the installation, all the controls should be examined.

The next test should be carried out on the detector and low-frequency circuits, with the aid of a pick-up, and, if possible, a gramophone. This test will indicate in which part of the receiver the defect has occurred.

The valves should now be checked with a good meter and valve adaptor, with the values which are shown on the chart on p. 689, and if necessary, replaced by good valves which have been previously tested. If it is not possible to place the receiver in good order, when these preliminary tests have been made, it will, in all probability, be necessary for the receiver to be examined in more detail in the workshop.

THE TYPE 830A SUPER INDUCTANCE RECEIVER

This receiver consists of two H.F. screened-grid circuits, a detector, and a L.F. transformer coupled to a pentode valve. It is fitted with two aerial sockets, marked λ1 and λ2. Aerial 1 is for local station reception, and it will be found, on reference to the circuit, that this is not mechanically connected, and operates by virtue of the small self capacity formed by the socket to the main receiving circuit. The volume control is effected by varying the grid voltage on the first H.F. valve. A permanent-magnet moving coil speaker is fitted inside the cabinet.

Low Voltage Circuit Test

The first test that should be applied to this receiver, and, in general, to all receivers, is a low-voltage circuit test, and this should be carried out with a D.C. meter having a resistance of 1,000 ohms per volt together with a 4-volt battery. This test is shown in Fig. 1, and the meter used is one that has a consumption of 1 milliamp for a full-scale deflection.

This low-voltage test will measure practically all values of circuit resistances, and at the same time it will be observed that no heavy currents are passed which are likely to seal an intermittent winding or joint.

Fig. 2.—First Stage in Dismantling the 830a Chassis. Removing the back.

Fig. 3.—Second Stage. Removing the fixing screws.

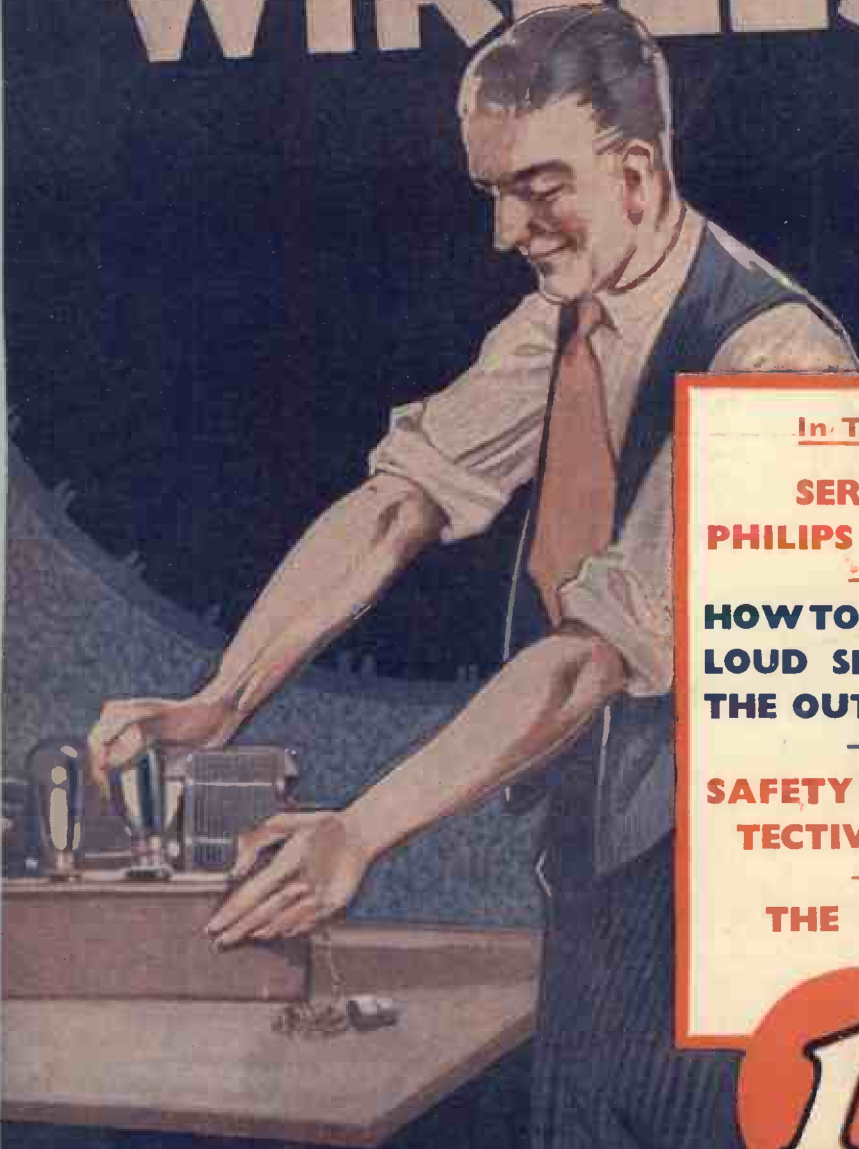
Points where Measurements should be Taken

The various points from which the measurements are taken and the values which should be obtained are as follows:—

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS



In This Part

SERVICING PHILIPS RECEIVERS

HOW TO MATCH THE LOUD SPEAKER TO THE OUTPUT STAGE

SAFETY AND PROTECTIVE DEVICES

THE STENODE

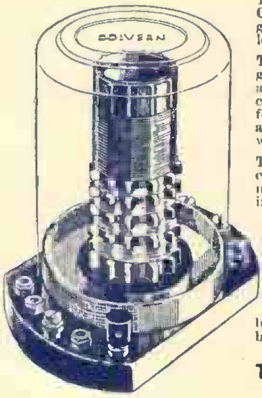
1/-

Part 15

IN ABOUT 24 WEEKLY PARTS

COLVERN
T.D. COIL

AN UP-TO-DATE COIL WITH UP-TO-DATE FEATURES



TYPE T.D., an entirely new COLVERN COIL, designed to give super selectivity on both long and broadcast wave-bands.

The coil is completely screened, giving a very neat appearance, and incorporates tapped aerial coupling and reaction, while the four alternative aerial tappings are arranged as sockets with a wander plug.

The first two tappings give aerial couplings similar to those normally employed but with greatly increased selectivity.

Nos. 4 and 5 give a high degree of selectivity with weak aerial coupling—suitable for use in a "swamp" area.

A most important feature of this coil is that there is no break through on the long waveband from B.B.C. stations.

TYPE T.D. - Price 8/6

Our 1933 Booklet Radio List No. 10 is now available and free on request.

COLVERN LIMITED
MAWNEYS RD. · · · ROMFORD, ESSEX

—and your batteries should be

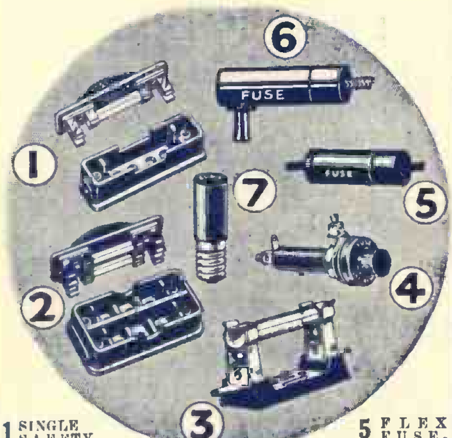
Exide

AND

Drydex

There is a type for every set.

FUSES and FUSE-HOLDERS



1 SINGLE SAFETY BASEBOARD FUSE-HOLDER 1/6
2 TWIN SAFETY BASEBOARD FUSE-HOLDER 2/6
3 SINGLE OPEN FUSE-HOLDER 9d.
4 PANEL FUSE-HOLDER 1/6
5 FLEX FUSE-HOLDER 1/-
6 WANDERFUSE 1/-
7 "SCRUFUSE" 6d. *Ratings:—60 m/a. 150 m/a. 250 m/a. 500 m/a. 750 m/a.*
8 SPARE FUSES. All ratings and sizes. 6d. each. *Each rating a different colour (avoiding possibility of error).*

BELLING-LEE
FOR EVERY RADIO CONNECTION

Advert. of Belling & Lee Ltd., Cambridge Arterial Road, Enfield, Middlesex.

Fifty Years the Family Favourite

TIT-BITS

Original Features and Popular Contributions

Big Cash Prizes Every Week

TIT-BITS

EVERY SATURDAY **TWOPENCE**

On sale at all Newsagents and Bookstalls, or by post 3d., from George Newnes Ltd., 8-11 Southampton St., Strand, London, W.C.2

Geo. Newnes Ltd.

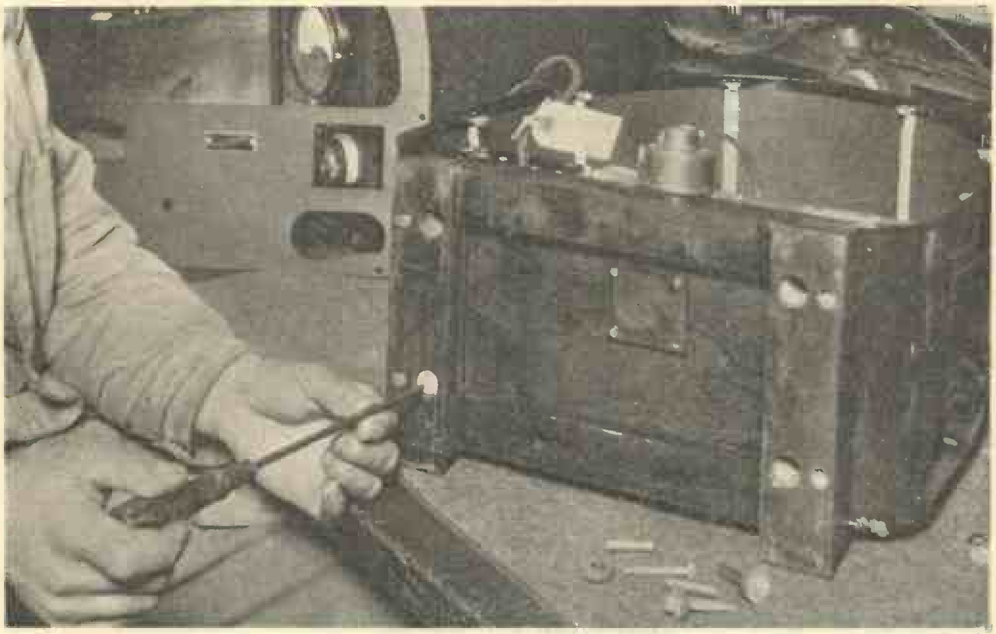


Fig. 4.—THIRD STAGE.
Removing the four screws on the underside.

Filament of 1821 valve to	
,, Plate of PM24A .	1,000 ohms
,, Screening grid of PM24A . .	Very low resistance
,, Plate of 244V . .	16,000 ohms
,, The second S4VB valve . . .	40 ,,
,, Screening grid of second S4VB valve	16,000 ,,
,, Plate of first S4VB .	8,000 ,,
,, Screening grid of first S4VB valve .	50,000 ,,
Grid of PM24A to chassis	0·1 megohm
,, 244V to chassis .	0·2 ,,
,, second S4VB to chassis . .	1 ,,
Screening grid of second S4VB to chassis	0·2 ,,
Grid of first S4VB valve to chassis . . .	0·125 ,,
The above values are approximate.	
Across the two pins of the wall plug with mains switch in circuit (varies with voltage tapping) .	100 ohms

Insulation

Between H.T. feed (filament of 1821 valve) to chassis (with highest available voltage approximately 200–400v.)	0·15 megohm

Fig. 5.—FOURTH STAGE.
Disconnecting the earth wire of the loud speaker.

Fig. 6.—Fifth Stage.

Removing the chassis. Note the method of handling. Care should be taken to see that the coil boxes are not roughly handled.

These tests will possibly show which part of the circuit is at fault, and the receiver should now be opened up for inspection.

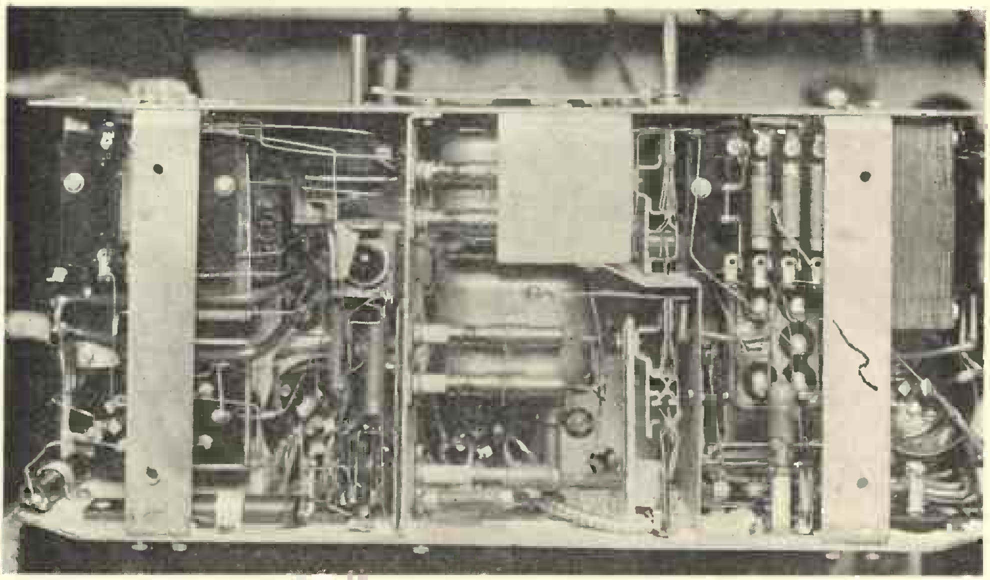


Fig. 7.—A View of the Underside of the Philips 830a Receiver.

Removing the Chassis

This should be done in the following way;—

(1) Remove the back (see Fig. 2).

(2) Remove the fixing screws (see Fig. 3).

(3) Remove the four screws on the underside (see Fig. 4).

(4) Disconnect the earth wire of the loud speaker (see Fig. 5).

(5) Remove the chassis. (Note carefully the method of handling. It is important that the coil boxes are not handled roughly (see Fig. 6).

When the instruments are examined in the works and service departments, special stands are used (see Fig. 8).

Handling and Refitting the Chassis

When handling or refitting the chassis, every care must be taken to ensure that the connecting wires are properly spaced.

The component parts can now be carefully examined, and Fig. 7 shows a view of the underside.

The mains transformer is in the top right-hand corner. The resistances R7, R3, R2 and R1 are fitted together on one base, below this is the condenser box, housing condensers C3, C4 and C8. The centre compartment contains the ganged condensers, and above these are the tubular trimming condensers. *On no account must these be touched.*

If either the coils or ganged or trimming condensers are at fault, the receiver must be returned to the works. The left-hand compartment contains the condenser pack C1, C2, C5, C7, C9 and C21. This is fitted on the top of the chassis. In addition to this, the L.F. transformer and resistances R8, R9, R4 and R10, are fitted in this part of the chassis.

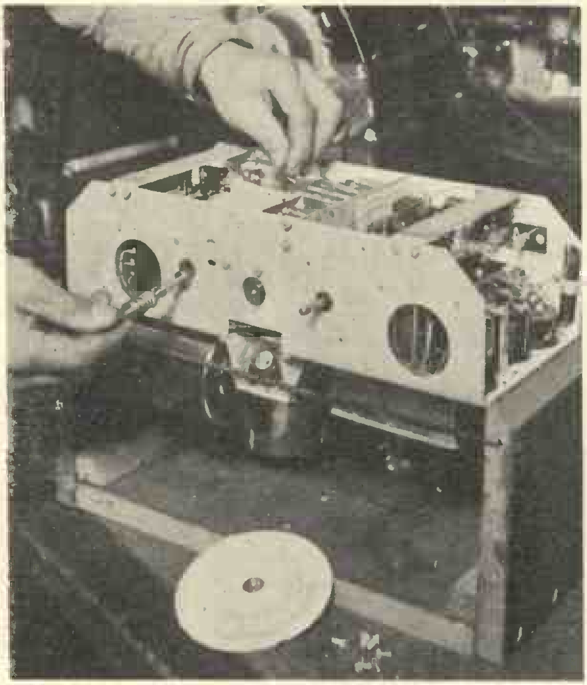


Fig. 8.—Adjusting the Wavechange Switch.

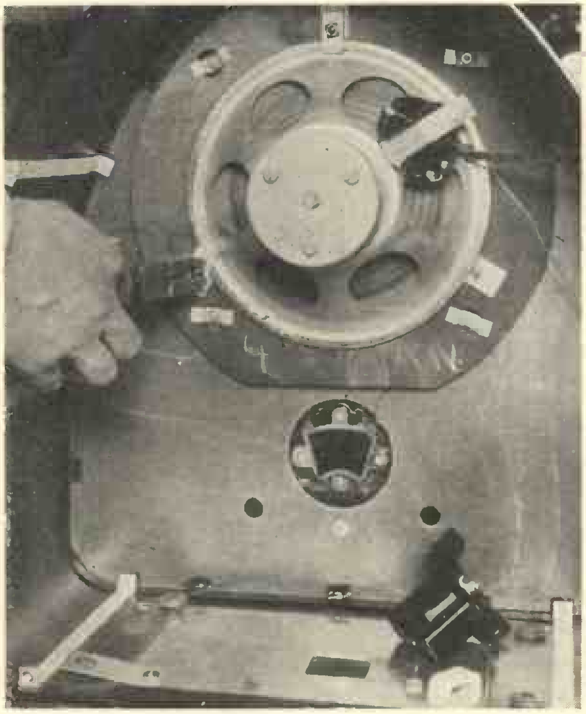


Fig. 9.—How to Remove the Loud Speaker.

Fig. 10.—How to Fit the Copper Screening Caps on the Screen-Grid Valves.

This shows the clip-on type of cap being fitted. All that is necessary is to press the white button, place on the threaded insert and release.

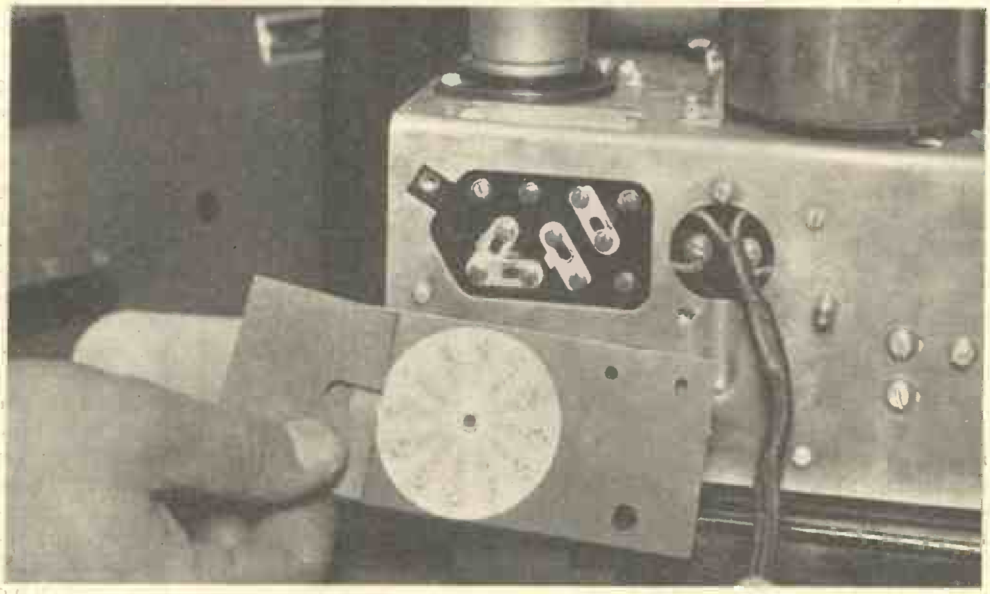


Fig. 11.—Changing the Voltage Range of the Mains Transformer.

On the underside of the cover plate will be found a disc giving the diagrams showing how the links should be connected for various voltages.

VALVE TABLE (TYPE 830a)

To Measure	Measure Between	Normal Readings	Reading Too High, Examine	Reading Too Low, Examine	Remarks
L2, S4VB (1)					
Plate voltage	Plate and cathode	160–175 v.		S10, S11, C4, R3	
Screen voltage	Screen grid and cathode	70–80 v.	R2	R1, C3	
Plate current	Plate	1·7–2·3 m.a.	R6–R7	L2, R6–R7, S10–11 R3, C4	
Grid circuit				S7–8–R9	Continuity test remove valve
L3, S4VB (2)					
Plate voltage	Plate and cathode	160–175 v.		S12, R10	
Screen voltage	Screen grid and cathode	70–80 v.		R4, C5, R10	
Plate current	Plate	1·7–2·5 m.a.	C16	L3, S12, C5, R4, 11 and 10	
Grid circuit				R18	Continuity test remove valve
L4, (244V)					
Plate voltage	Plate and cathode	75–85 v.		R4, C23, C5, S23	
Plate current	Anode	4·0–6·0 m.a.	C24, C17	L4, R13, R4, C5 S13, C23	
Grid circuit				R13	Continuity test remove valve
L5 (PM24A)					
Plate voltage	Plate and filament	145–175 v.		S16, S15, C20, C21, L1	
Aux. grid voltage	Screening grid and fil.	145–175 v.		L1	
Plate current		14–17 m.a.	S14, R8, S5	L1, L5, S15–16, C20–C21	
Grid circuit				S14, R8, S5	Continuity test remove valve
Heater voltage	Across filament	3·9–4 v.	Mains transformer	Mains transformer	

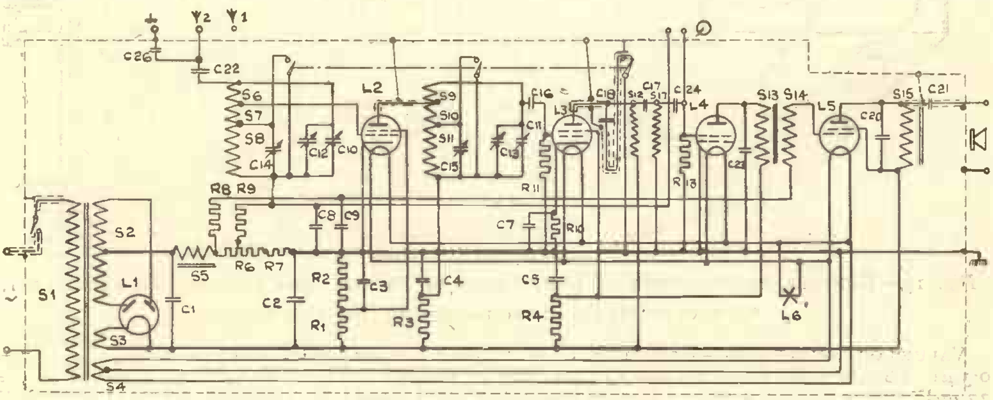


Fig. 12.—THEORETICAL CIRCUIT DIAGRAM OF PHILIPS TYPE 830A.

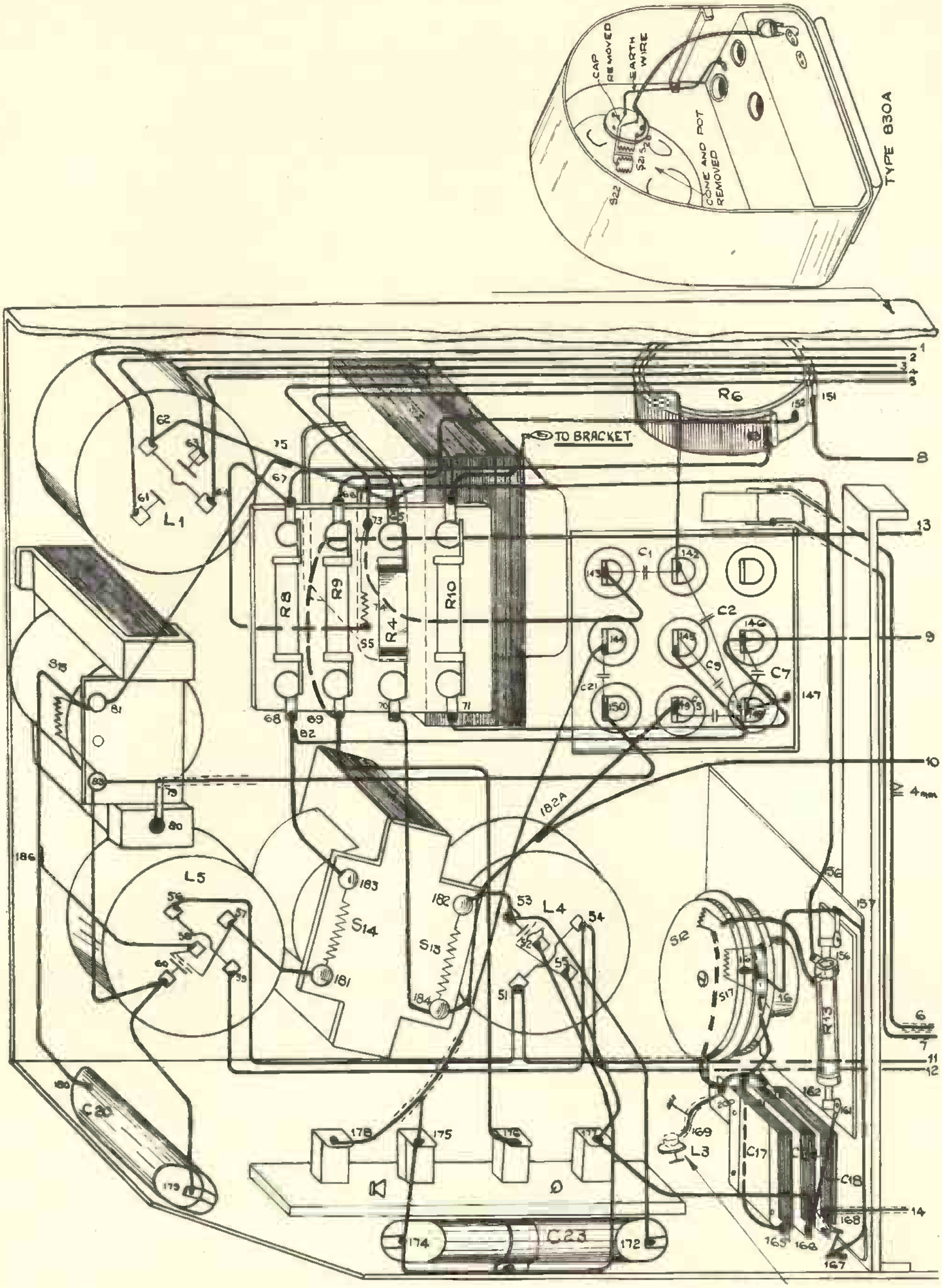


Fig. 13.—General arrangement of Components of Philips 830A (Bottom View) Sheet 1. Connect points 1–14 to corresponding points on Sheet 2.

Values of Condensers.—C1 = 3 μF, C2 = 2·5 μF, C3 = 0·5 μF, C4 = 0·5 μF, C5 = 1 μ F, C7 = 0·5 μF, C8 = 0·5 μF, C9 = 0·5 μF, C10 and C11 = 430 $\mu\mu$F, C12 = 10 $\mu\mu$F, C14, C15 and C13 = 27 $\mu\mu$F, C16 = 20 $\mu\mu$F, C18 = 1,000- or 800 $\mu\mu$F, C20 = 8,000 $\mu\mu$F, C21 = 0·1 μF, C22 = 20 $\mu\mu$F, C23 = 3,200 $\mu\mu$F, C17 = 640 or 800 $\mu\mu$F, C24 = 125 $\mu\mu$F, C26 = 100 $\mu\mu$F.

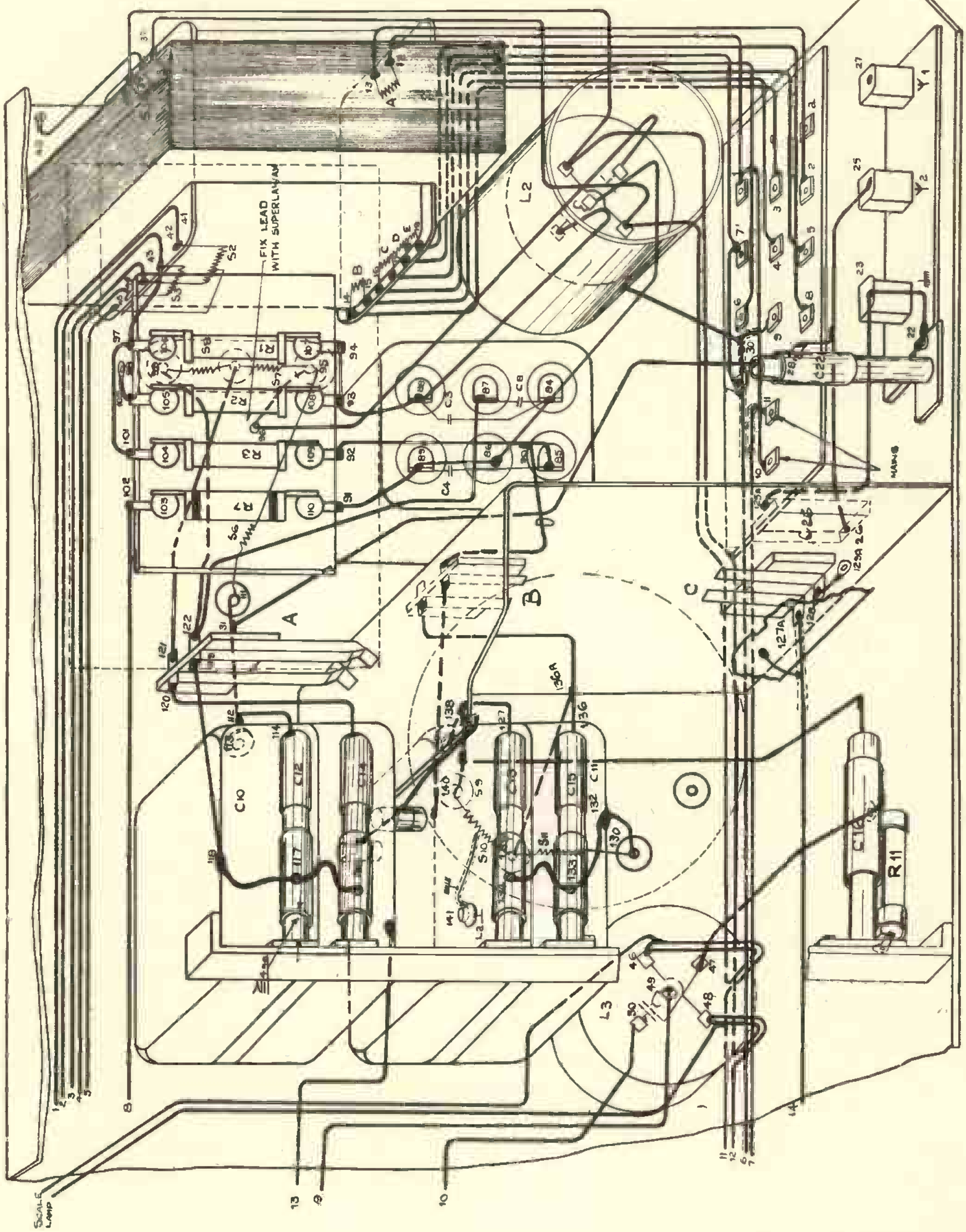


Fig. 14.—General arrangement of Components of Philips 830A (Bottom View) Sheet 2.
Connections 1–14 to be strapped to corresponding connections on Sheet 1.

Values of Resistances.—R1 = 50,000 Ω, R2 = 0·125 MegΩ, R3 = 8,000 Ω, R4 = 16,000 Ω, R6 = 600 Ω, R7 = 40Ω, R8 = 0·1 MegΩ, R9 = 0·2 MegΩ, R10 = 640 Ω, R11 = 1 MegΩ, R31 = 0·2 MegΩ.

How to make an Adjustment to the Wave-change Switch (Fig. 8)

The contact arm and springs of the wavechange switch can be readily seen, and adjustments to these contacts can be made very easily. If a bad contact is experienced, the switch should be cleaned and lubricated with a little vaseline.

If it is found that a breakage has occurred, a spare switch assembly can be obtained from the Service Department. The switch is actuated by the collar which can be seen close to the chassis in Fig. 8. This collar engages in a "U"-shaped metal arm, which forms the bottom end of the contact blade.

These switch assemblies are carried on brackets, which are secured to either side of the chassis with two screws, which are passed through slotted holes. Therefore they can be lined up with ease.

If it is found necessary at any time to remove the spindle, it can be done in the following manner :—

Release the small plate which is secured by two screws near the friction drive, slightly release the two screws which are at each end of the chassis which hold the bracket for the wavechange switch assemblies ; the small collar can then be released and the spindle withdrawn.

OHMIC RESISTANCES OF COILS. TYPE 830A

Circuit Designation.	Resistance in Ohms.	Remarks.
S8, S11	21—23	Test with low voltage. See under "type 830A."
S6–7, S9–10	3·2—3·3	
S12	31·0—37·0	
S13	340—420	
S14	1,460—1,780	
S15	925—1,135	
S17	129—157	

Replacing the Wavelength Scale

It will be observed that the scale is screwed on to the variable condenser spindle, but care must be taken to ensure that the calibration is correct when the scale is replaced.

How to Remove the Loud Speaker (Fig. 9)

The cover of the output transformer has been removed. It is only necessary to remove the three nuts which hold the clamps, as shown, and the loud speaker can be withdrawn. Box spanners should always be used wherever possible, but it is realised that these are not always available. Care should be taken that no metal filings or dust are allowed to collect in the gap.

How to Fit the Copper Screening Caps on the Screen Grid Valves (Fig. 10)

Some models were fitted with a screw-on cap. The caps should be held firmly in the hand and the valve top screwed home. In the majority of models, the clip-on type of cap is fitted. In this case, all that is necessary is to fit these on to the top of the valve, press the white button (shown under the first forefinger in Fig. 10), place on the threaded insert and release. Always test the cap to make sure that this is firmly secured.

Changing the Voltage Range of the Mains Transformer (see Fig. 11)

This type, in common with all recent Philips receivers, is equipped with a tapped mains transformer. The range covers any voltage between 100 and 253 volts.

Fig. 11 shows the link system, and the voltage of the mains transformer can be adjusted in the following way :—

Remove the three screws which secure the cover plate, and note from where the screws are taken. One of these screws has a "boat"-shaped washer. On the underside will be found the disc giving the diagrams showing how the links can be connected. Immediately above this will be found the voltage range ; alter the links accordingly, assure yourself that there are no loose screws or links, and replace the cover plate.

Replacing a Condenser Box

The condenser box, one of which is fitted to the top of the chassis, can be

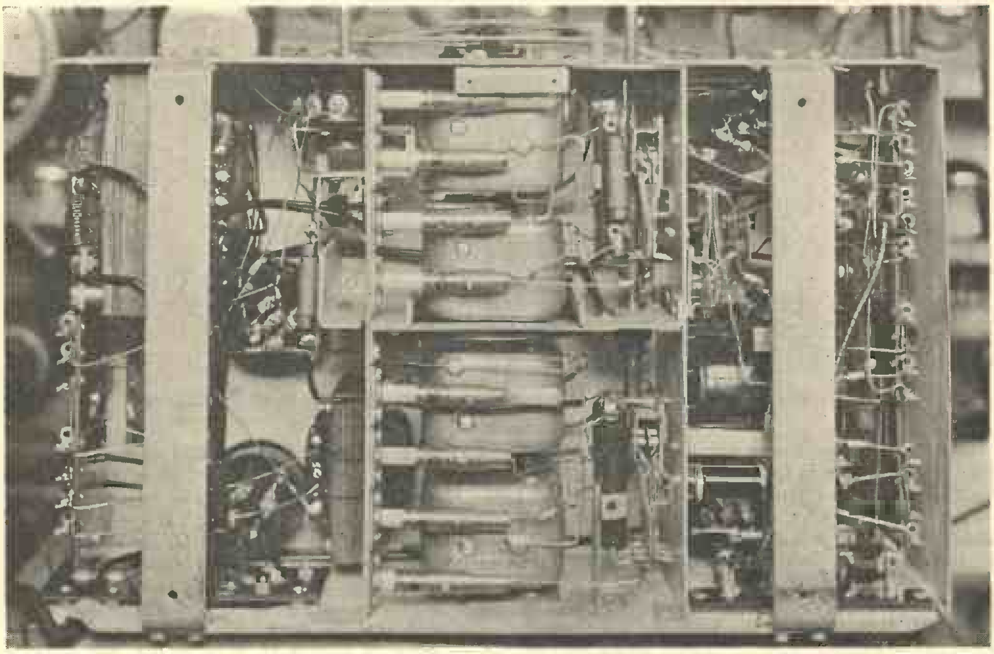


Fig. 15.—VIEW OF INTERIOR OF THE PHILIPS 630A CHASSIS.

Fig. 16.—METHOD OF SLIGHTLY OPENING THE SHUTTER GUIDE.

Fig. 17.—FITTING A MAINS TRANSFORMER FUSE REPLACEMENT.

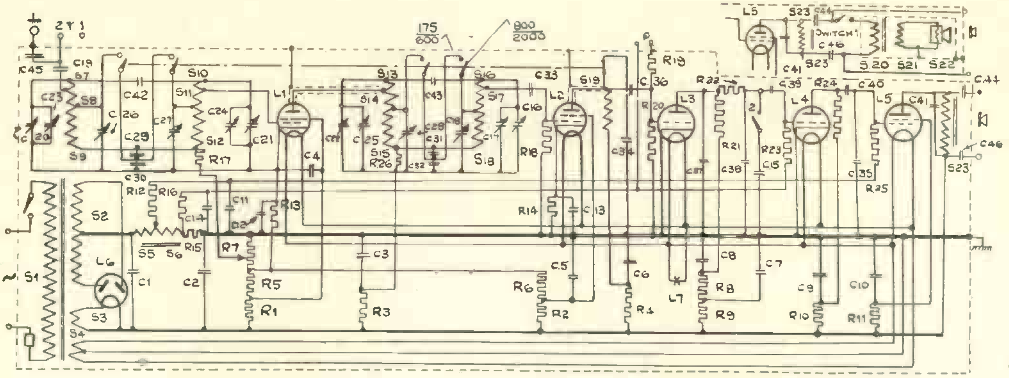


Fig. 18.—Theoretical Circuit Diagram of Philips 630a Receiver.

Condensers.—C1 = 3 μF, C2 = 4 μF, C4 = 1·5 μF, C3, C5 and C6 = 0·5 μF, C7 and C8 = 1 μF, C9, C10 and C11 = 0·5 μF, C12, C13 and C14 = 0·5 μF, C15 = 2,000 μμF, C16, C20 C21 and C22 = 430 μμF, C17, C23, C24 and C 25 = 10 μμF, C18, C26, C27 and C28 = 27 μμF, C19 = 40 μμF, C29 = 50,000 μμF, C30 and C31 = 50,000 μμF, C32 = 50,000 μμF, C34 = 640 μμF, C33 = 80 μμF, C35 = 1,600 μμF, C36 = 100 μμF, C37 = 2,000 μμF, C38 = 250 μμF, C39 = 8,000 μμF, C40 = 50,000 μμF, C41 = 2,000 μμF, C42 and C43 = 0·5 μμF, C44 = 0·2 μF, C45 = 80 μμF, C46 = 0·2 μF.

Resistances.—R1 and R2 = 50,000 Ω, R3 = 16,000 Ω, R4 = 20,000 Ω, R5 = 40,000 Ω, R6 = 64,000 Ω, R7 = 6,200 Ω, R8 = 10,000 Ω, R9 = 20,000 Ω, R10 = 20,000 Ω, R11 = 15,000 Ω, R12 = 0·1 MΩ, R13 and R14 = 400 Ω, R15 = 100 Ω, R16 = 0·5 MΩ, R17 = 1·0 MΩ, R18 = 1·0 MΩ, R19 = 0·32 MΩ, R20 = 0·2 MΩ, R21 and R24 = 32,000 Ω, R22 = 0·1 MΩ, R23 = 0·64 MΩ, R25 = 0·1 MΩ, R26 = 2,000 Ω.

replaced by carefully unsoldering the wires from the lugs, using a pair of tweezers and a soldering iron with a long bit. Note carefully from where the wires are taken. The screws which hold the bracket should now be taken out and the box can be removed.

Replacing Resistance

Care should be taken when replacing a resistance that the soldering operation is done quickly.

THE TYPE 630A SUPER INDUCTANCE RECEIVER

The Circuit

This receiver comprises two H.F. screened grid stages, a detector, and a two-stage L.F. amplifier with pentode output valve, and a permanent-magnet moving-coil loud speaker.

The H.F. amplifier consists of two double-capacity coupled band-pass filters, one is connected to the aerial circuit, and the other forms a coupling between the anode of the first screened-grid valve and the grid of the second screened-grid H.F. valve.

The second anode circuit is semi-aperiodic and peaks at approximately 550 metres and 1,900 metres respectively. Two switches are fitted at the rear. One is for disconnecting the internal loud speaker when it is only required to use an external speaker, and the other con-

OHMIC RESISTANCES OF COILS TYPE 630A

Circuit Designation.	Resistance in Ohms.	Remarks.
S9, S12, S15, S18.	21—23	*Note.*—Take readings across end of coils and not through switch.
S7–8, S10–11, S13–14, S16–17	3·2—3·3	Test with low voltage.
S5–6 . .	1,000—1,200	See under "Type 830A."
S19 . .	21—35	
S23 . .	925—1,135	
S20 . .	400—500	

VALVE TABLE (TYPE 630A)

To Measure	Measure Between	Normal Readings	Reading Too High, Examine	Reading Too Low, Examine	Remarks
L1, S4VB (1)					
Plate voltage .	Plate and cathode .	190–240 v.		S14, 15, C3, R3, R13, R26	
Screen grid voltage . .	Screen grid and cathode	100–110 v.	R5	R1, C4, R13	
Plate current .	Plate . .	1·6–3·0 m.a.	R7	L1, R7, R17, S14, 15, C3, R3 R13	Varies with R7
Grid circuit .				S11, S12, R17	Continuity test remove valve
L2, S4VB (2)					
Plate voltage .	Plate and cathode .	165–180 v.		S19, R4, C6, R14	
Screen grid voltage . .	Screen grid and cathode	100–110 v.	R6	R2, R14, C5	
Plate current .	Plate . .	3·0–4·0 m.a.	C33, C43	L2, S19, C6, R4, R18 R14	
Grid circuit .				R18	Continuity test remove valve
L3, 244V (1)					
Plate voltage .	Plate and cathode .	45–70 v.		R8, R9, R21, C7, C8, C37	
Plate current .	Plate . .	2·8–3·5 m.a.	C36	L3, R20, R21, R8–9 C7–8 and 37	
Grid circuit .				R20	Continuity test remove valve
L4, 244V (2)					
Plate voltage .	Plate and cathode .	105–135 v.		R20, R24, C9	
Plate current .	Plate . .	2·1–2·7 m.a.	C39, C14	L4, R10, R24, R16 R23, C9	
Grid circuit .				R23, R16	Continuity test remove valve
L5, PM24A					
Plate voltage	Plate and filament . .	210–230 v.		C41, S23, C44, C46	
Aux. grid voltage	Screening grid and fils. .	170–190 v.		S20, L6, R11, C10	
Plate current .		13–19 m.a.	C40, C11, C35	L5, L6, S23, C44, C46 S20, R25, R12	
Grid circuit .				R25, R12	Continuity test remove valve
Heater voltage all valves	Across filament	3·9–4·0 v.	Mains transformer	Mains transformer	

trols the filter circuit which provides a means of suppressing heterodyne whistle and needle scratch when used as a gramophone record reproducer.

The receiver is highly balanced and extremely selective owing to the method of coupling between the circuits. It is, therefore, essential that no attempt should be made to repair the components in the band-pass filter circuits.

General Notes

The method of testing described in the previous notes with regard to the Type 830A receiver, is recommended for this receiver.

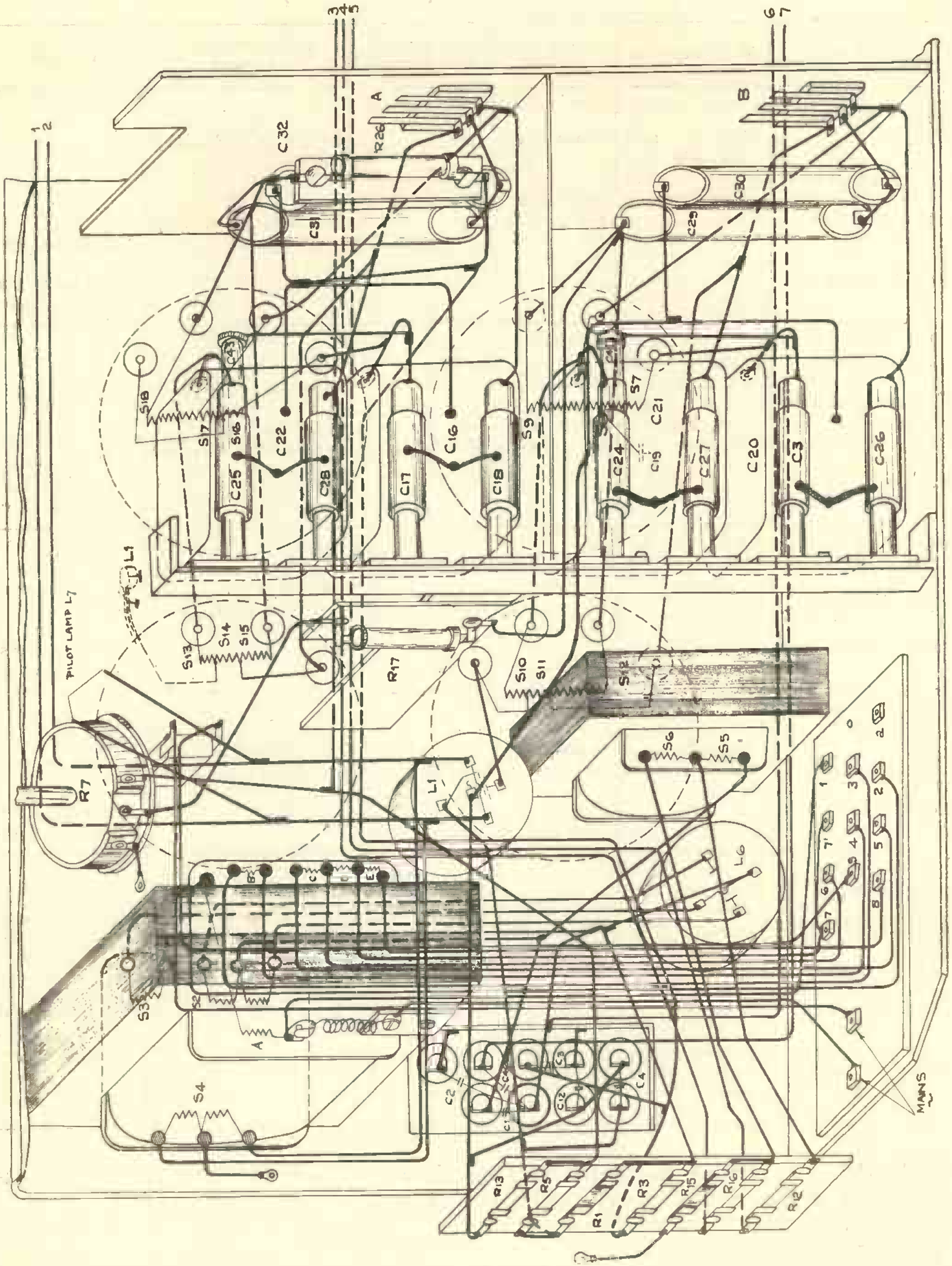


Fig. 19.—General arrangement of Components. Philips Receiver Type 630A. Sheet 1. Connect 1–7 to corresponding points on Sheet 2.

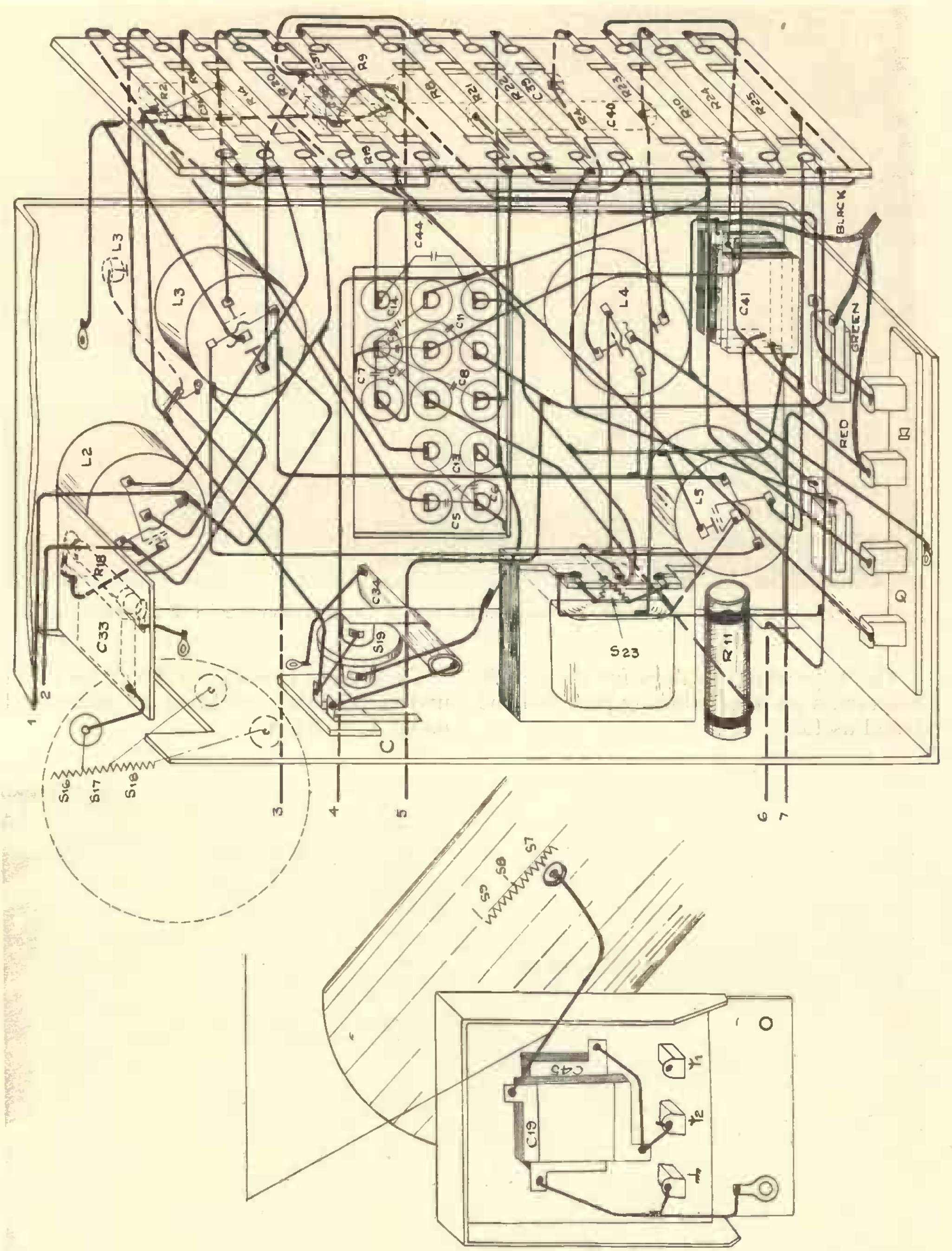


Fig. 20.—General arrangement of Components. Philips Receiver Type 630a. Sheet 2.
Connect 1–7 to corresponding points on Sheet 1.

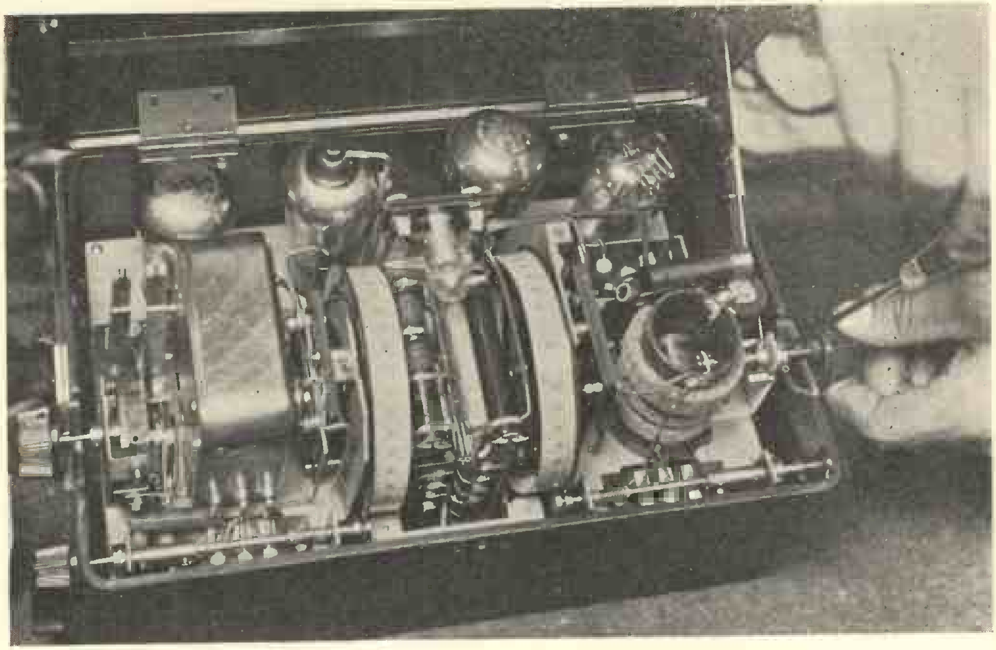


Fig. 21.—How to Remove the Knob of the Philips Type 2531 Receiver.

The approximate values for the circuit resistances on the following page will be found useful.

These resistance values should be taken under the same condition as mentioned under Type 830A.

Fig. 22.—How to Remove the Seals.

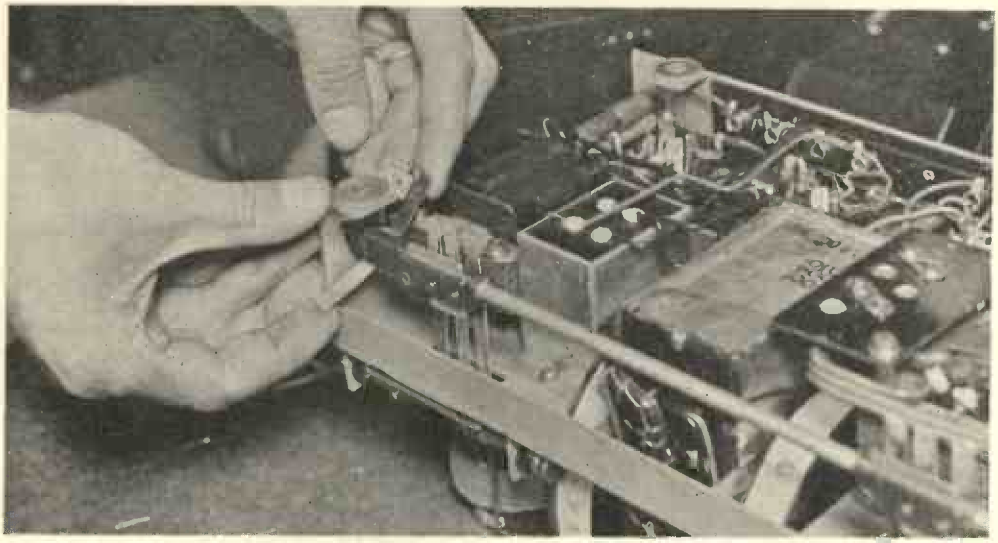


Fig. 23.—Fitting a New Wavechange Switch Spring

Filament of 1821 valve to	
Plate of first S4VB	18,000 ohms
Screening grid of S4VB	35,000 ,,
Plate of second S4VB	20,000 ,,
Screening grid of S4VB	40,000 ,,
Plate of detector 244V	60,000 ,,
,, first L.F. 244V	52,000 ,,
,, second L.F. 24A	1,000 ,,
Auxiliary grid L.F. 24A	16,000 ,,
Primary of mains transformer: Across wall plug and switch made } Varies with tapping	30 ,, approx.

Screening grid of first S4VB to chassis	35,000 ohms
Grid of first S4VB to chassis	1·0 megohm
Screening grid of second S4VB to chassis	45,000 ohms
Grid of second S4VB to chassis	1·0 megohm
Grid of detector 244 V to chassis	0·2 ,,
,, first L.F. 244V to chassis	1·0 ,,
,, 2nd L.F. 24A to chassis	0·2 ,,

If it is found necessary to remove the chassis, it can be done in the following way.

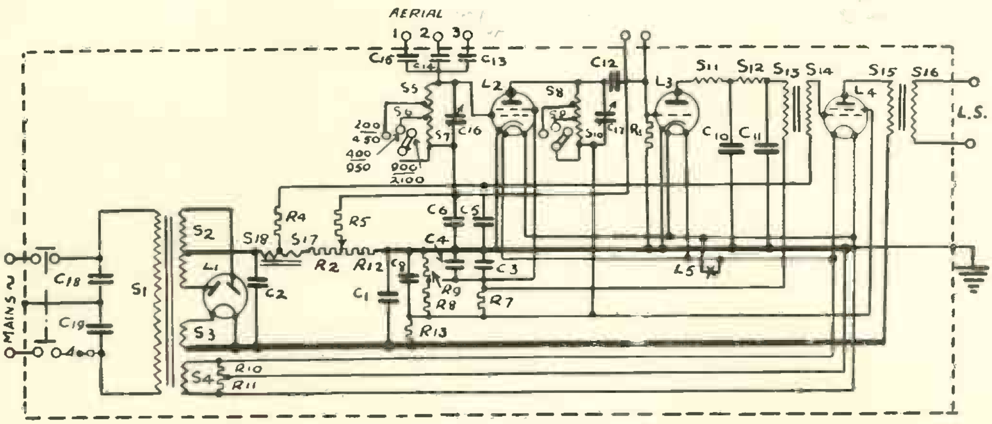


Fig. 24.—Theoretical Circuit Diagram of Philips Type 2531 Receiver.

Condensers.—C1 = 2 μF, C2 = 4 μF, C3 = 2 μF, C4 = 1 μF, C5 = 1 μF, C6 = 1 μF, C8 = 1 μF, C10 = 1,600 μμF, C11 = 500 μμF, C12 = 160 μμF, C13 = 280 μμF, C14 = 65 μμF, C15 = 17 μμF, C16 = 830 μμF, C17 = 550 μμF, C18 = 500 μμF, C19 = 500 μμF.

Resistances.—R1 = 1 MΩ, R2 = 220 Ω, R4 = 0·1 MΩ, R5 = 0·1 MΩ, R7 = 15,000 Ω, R8 = 28,500 Ω, R9 = 33,500 Ω, R10 = 120 Ω, R11 = 120 Ω, R12 = 35 Ω, R13 = 2,200 Ω.

Note Carefully

Before the chassis is taken out, turn the variable tuning condenser to the minimum position and observe the position of the two scales, *i.e.*, A5 :—

(1) Remove the valves.

(2) Remove the knobs by releasing the grub screws.

(3) Remove the four screws on the under side of the chassis.

It is very important that the chassis is held with care when making repairs, and we recommend that some method of supporting the chassis (see Fig. 8, 830A), so that the coil boxes are not damaged or roughly handled while tests and repairs are being made, otherwise the selective qualities of the instrument may be impaired.

It will also ensure that short circuits are not accidentally made to the interior wires.

(4) Disconnect the loud speaker leads and note the colours of each lead to ensure that they are reconnected correctly.

(5) The chassis can now be withdrawn from the cabinet.

Fig. 25.—Repairing the Strip Type of Fuse.

Interior of Chassis

Fig. 15 shows a view of the interior of the chassis. This is divided into three compartments, the left-hand side houses the mains transformer, which is in the top left-hand corner, with the spring fuse on the extreme left. The condenser box C1, C2, C3, C4, C12 and C46, which is fitted to the top of the chassis and a resistance bank carrying R12, R16, R15, R3, R1, R5 and R13. The mains choke, S5 and S6, and voltage tapping plate are fitted in the lower end of the compartment. The centre compartment houses the four ganged variable tuning condensers, together with the trimming and coupling condensers.

On no Account are these to be Altered

The wavechange switch is at the extreme right of the centre compartment.

The right-hand compartment contains the condenser box C5, C6, C7, C8, C9, C10, C11, C13, C14 and C44. This is fitted on top of the chassis. The resistance bank carrying R2, R6, R14, R20, R19, R9, R8, R21, R22, R4, R23, R10, R24 and R25, is on the extreme right.

Valve Table

The valve voltages and currents which can be measured, are given in the table on p. 691.

Faulty Movement of Shutter

Fig. 16 shows the method of slightly opening the shutter guide, if it is found that this tends to stick slightly on changing the wavelength.

Mains Transformer Fuse Replacement (see Fig. 17)

A copper strip projects from the windings of the mains transformer. The fuse link is connected between this strip and the spring. The primary current flows through this combination. When the windings heat up, a rise of temperature causes the heat to be readily conveyed through the strip to the small roller (which is soldered with " Woods " metal, melting at 96° C.) to the small metal part of the fuse link. The " Woods " metal will then melt and the link is broken apart,

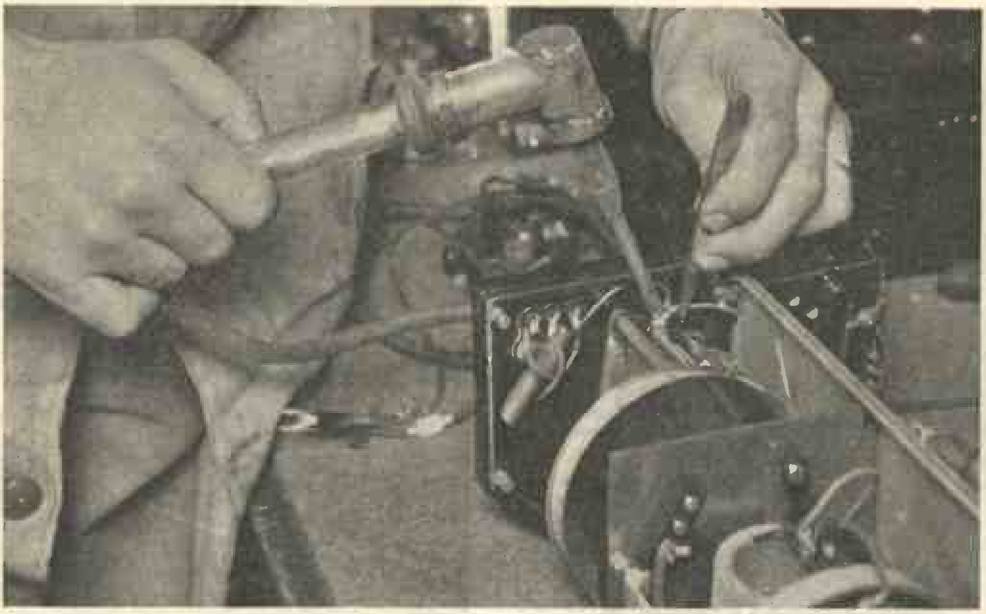


Fig. 26.—Disconnecting the Grid Lead to enable the H.F. Block to be Withdrawn.

thus interrupting the current. In order to make this part of the circuit good, it is only necessary to fit a new link and re-solder with the correct fuse metal.

When the new fuse has been fitted, always test the rectifying valve for electrode shorts, and also the insulation between H.T. positive and chassis before switching on the mains supply to the receiver.

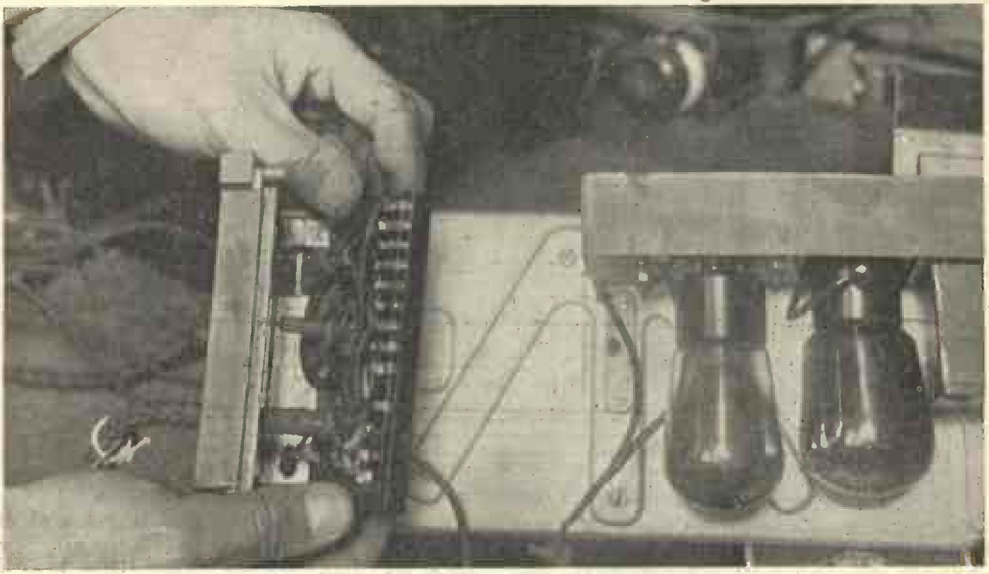


Fig. 27.—The H.F. Block Partially Withdrawn.

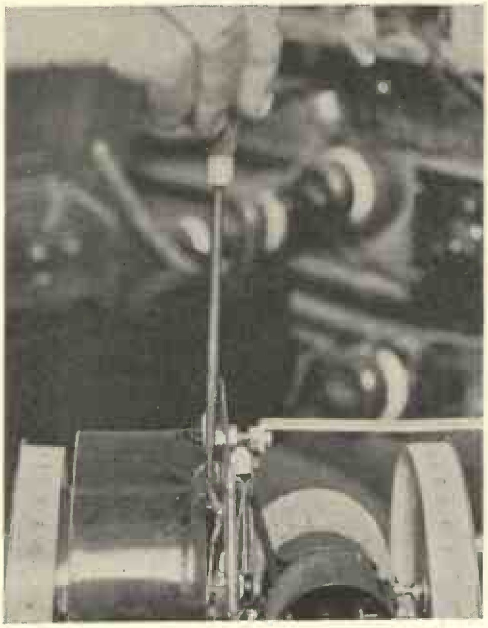


Fig. 28.—ADJUSTING THE WAVECHANGE SWITCH.

Fig. 29.—ADJUSTING THE REACTION CONTROL.

Replacement of a Faulty Resistance

The resistances are easily accessible, but care should be taken that the operation is done quickly so that the resistance is not damaged.

Replacing a Condenser Box

These units are fitted on top of the chassis. The wires should be resoldered with an iron having a long bit, and each wire should be noted to prevent errors when resoldering.

Changing the Voltage Range, and Adjustment to Wavechange Switch

See under Type 830A.

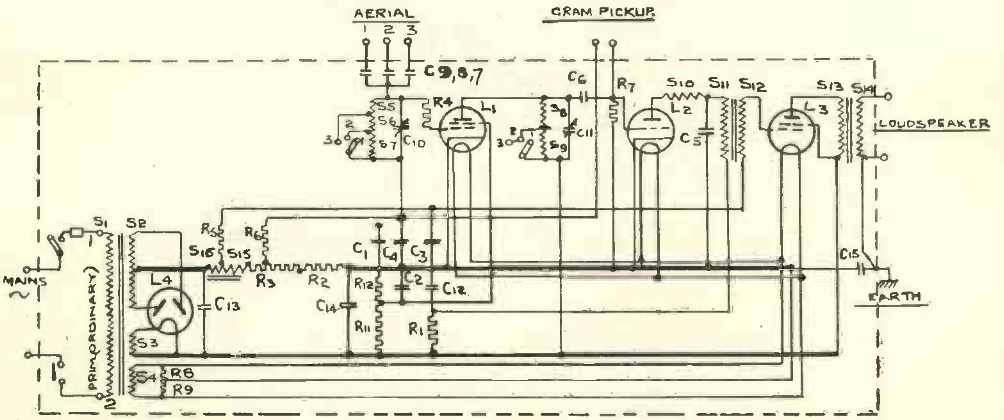


Fig. 30.—THEORETICAL CIRCUIT DIAGRAM OF PHILIPS TYPE 2514 RECEIVER.

CONDENSERS.—C1 = 1 μF, C2 = 1 μF, C3 = 1 μF, C4 = 1 μF, C5 = 1,000 cm., C6 = 150 cm., C7 = 250 cm., C8 = 60 cm., C9 = 15 cm., C10 = 750 cm., C11 = 750 cm., C12 = 2 μF, C13 = 4 μF, C14 = 6 μF, C15 = 90,000 cm.

RESISTANCES.—R1 = 15,000 Ω, R2 = 60 Ω, R3 = 240 Ω, R4 = 500 Ω, R5 = 0·1 MΩ, R6 = 0·1 MΩ, R7 = 1 MΩ, R8 = 120 Ω, R9 = 120 Ω, R11 = 28,500 Ω, R12 = 33,500 Ω.

Refitting the Chassis

When the chassis is refitted, every care must be taken to ensure that the scales coincide with the hairline at the exact point which was indicated before the chassis was removed. The screws on the underside should be partly screwed home and finally secured when the scales are in the correct position.

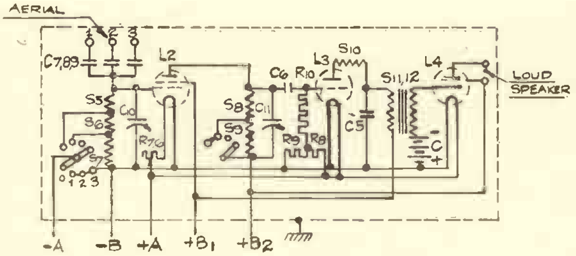


Fig. 31.—Simplified Circuit of Philips Type 2502 Receiver.

Condensers.—C5 = 1,000 cm., C6 = 150 cm., C7 = 15 cm., C8 = 60 cm., C9 = 250 cm., C10 = 750 cm., C11 = 750 cm.

Resistances.—R6 = 5·5 Ω, R7 = 60 Ω, R8 = 200 Ω, R9 = 120 Ω, R10 = 1 MΩ.

TYPE 2531—2534 3-VALVE A.C. RECEIVER AND SIMILAR TYPES

General Notes on Earlier Models

A few hints on the above and similar types of receivers will be found useful, and details are given below of a small number of minor repairs and adjustments which may occasionally be found necessary.

Removing the Knobs (see Fig. 21)

Remove the top metal screening cover. The knobs and slotted spindles are one complete fitting, and are held in additional hollow spindles, which are secured to the controlling components. Fig. 21 shows the method of removing the knob and spindle. It is held by a collar, which is secured to the spindle by a grub screw, which engages in the slot.

Release the grub screw and the knob can be removed. This method applies to all the knobs on the above types.

Removing the Seals (see Fig. 22)

A special type of seal is fitted in these models, and a threaded washer which holds the screw is sealed with a special low-temperature metal. Unscrew the foot, and with a pair of special long-nosed pliers secure a firm hold in two of the circular openings of the washer, and turn in the normal way. When these are released, the chassis can be withdrawn completely from the case. It is not always necessary to remove the complete case, as this instrument carries a subsidiary base, and an inspection can be made of the interior, when this base is removed by releasing the screws.

Fitting a New Wavechange Switch Spring (see Fig. 23)

The wavechange spring can be seen between the two forefingers in Fig. 23. One end is secured to the bracket close to the securing washer with a screw, the other is held by tension on the opposite side.

Repairing the Strip Type of Fuse (see Fig. 25)

This fuse may break by electric heating or mechanical shock. It is very important that this operation should be done carefully, and in the manner recommended. If there is no tension on the spring the fuse will not operate.

Therefore, make sure that the fuse strip is fitted so that there is tension.

Observe closely, from Fig. 25, how the strip is held in position, resolder carefully with "Woods" metal, melting at a temperature of 96° C.

Shorting Clips

It will be observed that this receiver carries two clips in the lid, which are part of a safety switch. Therefore, when making electrical tests on the receiver with the lid open, the two pairs of spring clips which are situated on the top of the chassis should be shorted.

TYPES 2502, 2514 AND SIMILAR RECEIVERS

Additional hints on the more common adjustments to these receivers are given below.

These receivers can be easily opened by removing the slide and taking out the screws which surround the leatherette case.

Disconnecting the Grid Lead to enable the H.F. Block to be Withdrawn (see Fig. 26)

Note carefully the method of this operation, particularly the useful tweezers for handling the lead which is being disconnected.

H.F. Block partially Withdrawn (see Fig. 27)

This shows the H.F. portion of the receiver partially withdrawn in order that attention may be given either to the volume control and/or battery cable if the receiver is a Type 2502.

This part of the receiver can be released by withdrawing the grid battery if it is a Type 2502. If the receiver is a Type 2514, release the screws of the mains transformer and condenser box and turn them over quite clear of the chassis complete with the leads. The H.F. block is secured with two bolts and nuts, and when these are removed the moulded block can be withdrawn.

Adjustment of Wavechange Switch (see Fig. 28)

The receiver may have been in use for some considerable time, therefore the switch contacts may require adjustment. The contacts are clearly shown in Fig. 28 being levered slightly in order to obtain a low resistance contact.

Adjustment of the Reaction Control (see Fig. 29)

The spindle of the reaction control is held in a split collar. This can be easily tightened by the method shown in Fig. 29.

Note that the slide forms a part of the safety switch. Therefore, when making electrical tests, it is essential that the spring contacts are shorted.

Operating Philips Receivers

If, after being installed, a set does not work satisfactorily, the following possibilities should be considered :—

(1) The valves may make poor contact ; clean their pins and push them well home in their sockets.

(2) The aerial, earth, or mains connections may make poor contact.

(3) The aerial-earthing switch, if any, may be in the wrong position.

(4) The mains socket may not be alive. This can be tested with a standard lamp.

If a valve does not get warm after the set has been switched on for some time, it may have become defective. Make sure by substituting another valve of the same type.

Generally speaking, Philips receivers will operate satisfactorily with an outside aerial between 40 and 80 feet in length, and a direct earth connection taken either to a copper earth tube or a main water pipe.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION VII—TUNED CIRCUITS

WE have discussed very briefly the impedance of a few of the simpler circuits occurring in radio practice. In particular, we dealt with the circuit comprising an inductance, possessing resistance, joined in series with a capacity. The circuit is reproduced again in Fig. 1. This case is important in radio work, since it is the simplest case of a TUNED CIRCUIT (this term is explained at the commencement of Section IV. in this series).

The vector impedance of this circuit is:—

$$z = R + j\left(L\omega - \frac{1}{C\omega}\right),$$

and the line O*r* in Fig. 2 represents the actual impedance of the circuit. The lines *pq* and *qr* represent the positive and negative reactances, respectively, viz., $L\omega$ and $\frac{1}{C\omega}$, and *pr* is the resultant arising from the addition of these two, viz., $\left(L\omega - \frac{1}{C\omega}\right)$. The line O*p* represents the pure resistance of the circuit, and it is perpendicular to the direction *pq*. The direction O*r* is oblique to *pq*, and measurement of the lines O*p* and O*r* will show that O*p* is the shorter. Whatever the position of *r* along *pq*, O*p* will always be shorter than O*r*. It is almost intuitive knowledge that the shortest distance from a point to, say, a wall, or a line drawn on the ground, is along the direction which is perpendicular to the wall or line. In this case O*p*, the perpendicular from O on the line *pq*, is the shortest line which can be drawn from O to *pq*. It does not matter whether *r* is above the OX axis or below it as in Fig. 3, where the negative reactance is greater than the positive reactance, O*p* is always the shortest distance from O on *pq*.

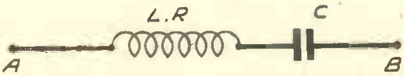


Fig. 1.—CIRCUIT COMPRISING AN INDUCTANCE POSSESSING RESISTANCE JOINED IN SERIES WITH A CAPACITY.

What happens when Negative and Positive Reactances are Equal

Suppose now that the negative reactance is just equal to the positive reactance. The lines *pq* and *qr* will be equal to each other, and the point *r* will coincide with *p*. In this case O*r* is the same as O*p*. That is to say, the impedance—which is represented by O*r*—is also represented by O*p*. But O*p* is the shortest line which can be drawn from O to the direction *pq*, and hence the impedance has its least value when *pq* just balances *qr*. When O*r* is in any other position it is oblique to *pq* and the impedance is greater than the value represented by O*p*. Thus the impedance of the circuit of Fig. 1 has its minimum value when the positive and negative reactances cancel out, *i.e.*, when the total reactance is zero. Expressing this condition in the shorthand notation of an equation we have :—

z = minimum value when

$$L\omega - \frac{1}{C\omega} = 0 \qquad (1$$

For all other values of the reactance—*i.e.*, $L\omega$ greater than $\frac{1}{C\omega}$, or *vice versâ*—the impedance is greater than this minimum value. We also know the actual value of the minimum impedance. It is represented by O*p*, but O*p* represents the pure resistance of the circuit, and hence the

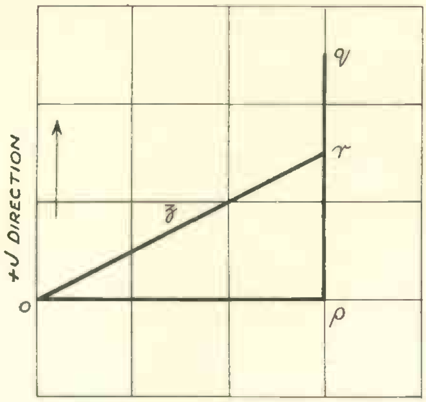


Fig. 2.—THE LINE O*r* SHOWS THE ACTUAL IMPEDANCE OF THE CIRCUIT OF FIG. 1.

minimum impedance equals the pure resistance of the circuit, thus :—

$$z = \text{R when}$$

$$\text{L}\omega - \frac{1}{\text{C}\omega} = 0.$$

Now when the difference of two quantities is equal to zero the two quantities must be equal to each other, hence :—

$$\text{L}\omega = \frac{1}{\text{C}\omega} \quad . \quad . \quad (2)$$

This expresses the same fact as (1). It tells us a relation between L, C and ω when the impedance is a minimum. It means nothing when the impedance is not a minimum. Conversely, when this relation exists — *i.e.*, when the inductance, capacity and frequency of the current are such that Lω and $\frac{1}{\text{C}\omega}$ are equal —the impedance is a minimum. Multiply both sides of (2) by Cω :—

$$\text{L}\omega \times \text{C}\omega = \frac{1}{\text{C}\omega} \times \text{C}\omega$$

The terms on the right-hand side cancel, leaving :—

$$\text{LC}\omega^2 = 1 \quad . \quad (3)$$

and this is the usual form in which the

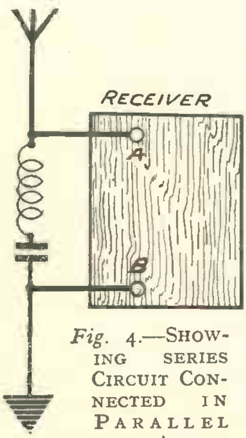


Fig. 4.—SHOWING SERIES CIRCUIT CONNECTED IN PARALLEL WITH AERIAL AND EARTH TERMINALS OF A SET, TO FORM A WAVETRAP.

condition of minimum impedance is usually expressed. Why is this condition of importance in radio design ?

Why Minimum Impedance is Important in Radio Design

Suppose that we connect the circuit of Fig. 1 to a source of signals of various wavelengths or frequencies, such as an aerial. The circuit will offer a certain effective resistance to the signals, but to one particular signal it will offer the least impedance, and this will occur when the frequency of the signal is such that the condition of minimum impedance is satisfied, viz., the condition expressed by (3). This frequency can be calculated if we substitute $2\pi f$ for ω (we made the reverse substitution in Section VI.). We have :—

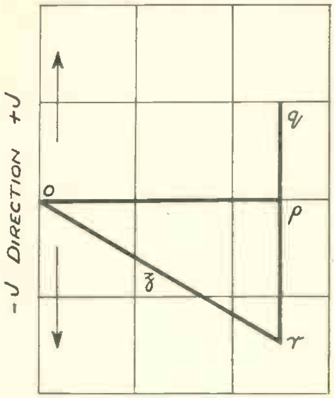


Fig. 3.—SHOWING THAT NO MATTER WHETHER *r* IS ABOVE THE OX AXIS OR BELOW IT, O*p* IS ALWAYS THE SHORTEST DISTANCE FROM O OR *pq*.

$$\text{LC}\,(2\pi f)^2 = 1 \quad . \quad . \quad (4)$$

i.e.,

$$\text{LC}\,4\pi^2 f^2 = 1 \quad . \quad . \quad (4a)$$

and hence minimum impedance is obtained when the frequency is such that when squared and multiplied by (LC$4\pi^2$) the answer is 1.

In (4a) the frequency is in cycles per second when L is in henries and C is in farads. We can express this in a form more convenient for calculating f when L and C are known. Dividing each side by LC $4\pi^2$, we have :—

$$\text{LC}\,4\pi^2 f^2 \div \text{LC}\,4\pi^2 = 1 \div \text{LC}\,4\pi^2,$$

i.e.,

$$f^2 = \frac{1}{\text{LC}\,4\pi^2}.$$

Taking the square root :—

$$f = \sqrt{\frac{1}{\text{LC}\,4\pi^2}},$$

which may be written as :—

$$f = \frac{1}{\sqrt{LC4\pi^2}}$$

Now $\sqrt{LC\,4\pi^2} = \sqrt{LC} \times \sqrt{4\pi^2}$,

i.e., $\sqrt{LC\,4\pi^2} = \sqrt{LC} \times 2\pi$.

Hence $$f = \frac{1}{2\pi\sqrt{LC}} \quad . \quad (5)$$

Converting Formula (5) so that L and C are in microhenries and microfarads respectively

It is usual in wireless circuits to express the inductance in microhenries (mH.) and the capacity in microfarads (mfd.). Hence if L and C be measured in these units we must convert them into henries (H.) and farads (F.) respectively.

i.e., $$\text{L mH.} = \frac{L}{10^6}\text{ H.}$$

and $$\text{C mfd.} = \frac{C}{10^6}\text{ F.}$$

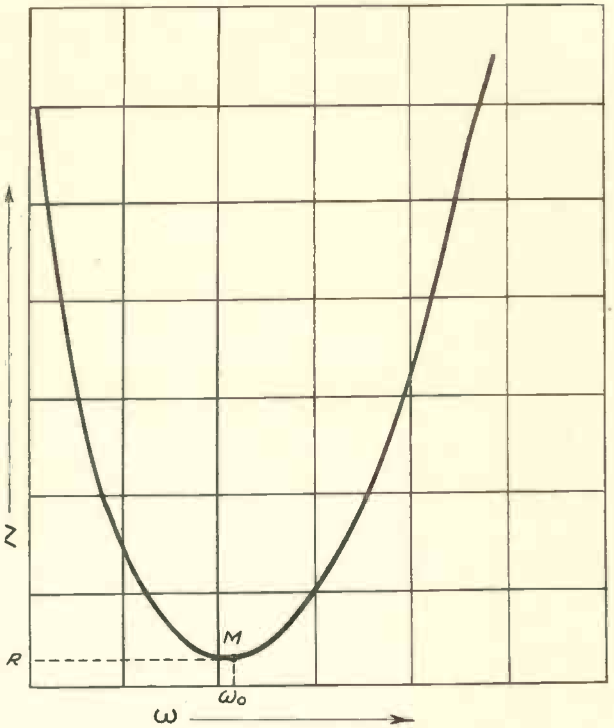


Fig. 5.—Graph showing Impedance at Various Frequencies.

Hence, writing these values in (5), we have :—

$$f = \frac{1}{2\pi\sqrt{\frac{L}{10^6} \times \frac{C}{10^6}}},$$

i.e., $$f = \frac{1}{2\pi\frac{\sqrt{L \times C}}{\sqrt{10^6 \times 10^6}}},$$

i.e., $$f = \frac{1}{2\pi\frac{\sqrt{LC}}{10^6}}.$$

or $$f = \frac{10^6}{2\pi\sqrt{LC}} \quad .. \quad . \quad (6)$$

where L and C are now in microhenries and microfarads, and f is in cycles per second. Equation (6) expresses the same condition as (1), but in a more convenient form for calculation. In illustration of the use of (6), consider the case of a circuit in which L = 250 mH., and C = ·0004 mfd., we have :—

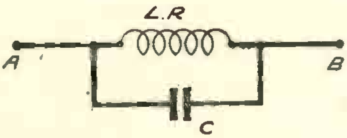


Fig. 6. — An Inductance in Parallel with a Capacity.

$$LC = 250 \times \cdot 0004$$

i.e., $LC = \cdot 1$

Thus the circuit offers minimum impedance to a frequency :—

$$f = \frac{10^6}{2\pi\sqrt{0\cdot 1}} \text{ cycles per second,}$$

i.e., $$f = \frac{10^6}{2 \times 3\cdot 1416 \times \cdot 3165} \text{ cycles per second,}$$

i.e., $f = 503{,}500$ cycles per second (approx.)

or $f = 503\cdot 5$ kc/s.

That is to say,

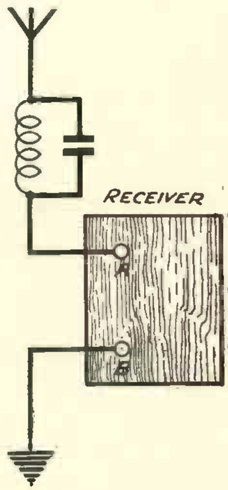


Fig. 7. — How a Parallel Circuit can be used as a Wavetrap.

a coil of 250 mH. inductance and a capacity of ·0004 mfd., joined in series will offer minimum impedance to a signal of frequency 503·5 kc/s., and this minimum impedance is equal to the pure resistance of the coil. This frequency corresponds to a wavelength of 596 metres (approx.). To signals of all other frequencies or wavelengths the impedance will be much greater than the pure resistance of the coil.

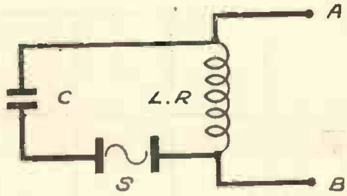


Fig. 8.—SHOWING THE SIGNAL SOURCE IN SERIES WITH THE TWO CIRCUIT ELEMENTS.

Using the Circuit as a Wavetrap

An immediate application of this circuit is as a wavetrap. Suppose that we connect it in *parallel* with the aerial and earth terminals of a receiver, as in Fig. 4, and suppose that the values of L and C are such that the circuit offers minimum impedance to signals of the same frequency as that of the local station. This is easily arranged by employing a variable condenser and adjusting it until this condition obtains. Then, since electrical signals always tend to travel along the path of least resistance, the local station signals will be passed through the wavetrap, since the path from A to E inside the receiver is of much greater impedance than that of the wavetrap. The impedance of the wavetrap will be greater for signals of other wavelengths, and hence these will operate the receiver in the usual manner. If the wavetrap coil is carefully designed so that its pure resistance is practically nil, then the wavetrap will act almost as a short-circuit to the local station signals.

Resonant Frequency

As we adjust the capacity of the condenser C we are actually adjusting the circuit so that it offers minimum impedance to the local station signals. This process is known by the familiar name of "tuning." The frequency for minimum impedance is often called the RESONANT FREQUENCY, and the whole operation of tuning the circuit so that $L\omega = \frac{1}{C\omega}$ is known as tuning to RESONANCE, or causing the circuit to RESONATE, with the particular frequency f. (NOTE.—f is the frequency of the signal, and ω is called the ANGULAR FREQUENCY. The reason for this name is explained in every good text book of radio engineering.)

Graph showing Impedance at various Frequencies

The shape of the graph showing the impedance at various frequencies is shown in Fig. 5. Note that in this case we are not concerned with an exact curve, but only with the general shape of the curve, and hence no numerical values are marked along the axes. The arrows show the directions in which Z and ω increase. We see from this that a minimum value of Z is reached at the point marked M, and the impedance increases rapidly when the frequency is only slightly different from the resonance value, marked ω_0, corresponding to M. Throughout these articles we shall use ω_0 as a shorthand for the angular frequency at resonance. Thus, whenever we write ω_0 we know that its value is such that :—

$$L\omega_0 = \frac{1}{C\omega_0}.$$

How Frequency of a Signal is expressed in Terms of its Wavelength

We can express the frequency of a signal in terms of its wavelength λ, thus :—

$$f = \frac{V}{\lambda}$$

where $V = 300 \times 10^6$, and is the value of the velocity of wireless waves in metres per second. Writing this value for f in (6) we have :—

$$\frac{V}{\lambda} = \frac{10^6}{2\pi\sqrt{LC}}$$

i.e.,

$$\frac{300 \times 10^6}{\lambda} = \frac{10^6}{2\pi\sqrt{LC}}$$

cancelling the 10^6 from each side, and inverting both sides we have :—

$$\frac{\lambda}{300} = \frac{2\pi\sqrt{LC}}{1}$$

i.e.,

$$\lambda = 300 \times 2\pi\sqrt{LC}$$

writing 3·1416 for π, and then replacing $300 \times 2\pi$ by 1,885, we have finally :—

$$\lambda = 1{,}885\sqrt{LC} \quad . \quad . \quad (7)$$

This is the well-known formula giving the wavelength to which a circuit resonates in terms of the inductance and capacity. As in (6), L and C are in microhenries and microfarads respectively.

As an example, consider the case of an inductance of 3,000 mH. and a capacity of ·0003 mfd., we have :—

$$LC = 3{,}000 \times \cdot 0003$$

i.e., $$LC = \cdot 9$$

Thus the circuit offers minimum impedance to signals whose wavelength (λ) is :—

$$\lambda = 1885 \times \sqrt{\cdot 9} \text{ metres}$$

i.e., $$\lambda = 1885 \times \cdot 95 \text{ metres}$$

$$\lambda = 1790 \text{ metres.}$$

That is to say, an inductance of 3,000 mH. and a variable condenser of ·0003 mfd. maximum capacity will tune to a wavelength just greater than that of Radio Paris, and hence the combination could be used as a wavetrap for Daventry or Radio Paris in the manner just described.

Inductance in Parallel with a Capacity

This resonance condition also applies to another form of tuned circuit, widely used in radio practice, viz., the parallel circuit in which an inductance, possessing resistance, is joined in parallel with a capacity (see Fig. 6). The expression for the impedance of this circuit is very complex and we shall only be concerned with the impedance at the resonant state. At resonance the impedance is a *maximum*, and resonance occurs when the condition expressed by (1) and (7) obtains. Since the parallel circuit behaves in a manner similar to that of the series circuit at or near the resonant frequency it is often represented by the simpler series circuit for ease of manipulation.

How a Parallel Circuit can be used to reject unwanted Signals

We have seen that the series circuit can be used as a wavetrap. In a similar way the parallel circuit can be connected in *series* with the aerial lead to a receiver (see Fig. 7) and tuned to the wavelength of the local station, or of any interfering station, so that the interfering signals are rejected. The circuit offers maximum impedance—which is very large—to these signals, and hence almost completely prevents their operating the receiver. Signals of wavelengths greater or less than the resonant value are almost unaffected and operate the receiver in the normal manner.

Effect of Resonance on a Parallel Circuit

Now consider the parallel circuit of Fig. 6 when resonance occurs. As already stated it can be represented by the simpler series circuit, and it is re-drawn in this way in Fig. 8, the signal source now being in series with the two circuit elements. We shall suppose that the voltage of the signal source is e_s. Provided that no current is taken from the circuit at A and B, the same current will pass through both L and C. Let this current be i. Suppose that the voltage across the terminals A and B is used for operating a receiver. We have to find the voltage across AB in terms of the input voltage (e_s), and the inductance and capacity of the circuit.

At resonance $L\omega = \frac{1}{C\omega}$, hence the impedance of the circuit is R, the pure resistance of the coil, and thus, by Ohm's law we have :—

$$e_s = iR \quad . \quad . \quad (8)$$

Now the impedance of the portion AB of the circuit is :—

$$Z = \sqrt{R^2 + (L\omega)^2}$$

In practice R is very small compared with $L\omega$ (certainly less than $\frac{1}{5}$th of $L\omega$), hence R^2 can be neglected in this expression, giving :—

$$Z = L\omega$$

Now the voltage produced across the ends of a circuit of impedance Z and carrying current i is equal to the product of i and Z. Hence :—

$$e_{AB} = iZ$$

i.e., $$e_{AB} = i\,L\omega \quad . \quad . \quad (9)$$

where e_{AB} is the voltage across AB.

Dividing (8) into (9), we see that :—

$$\frac{e_{AB}}{e_s} = \frac{i\,L\omega}{iR}$$

i.e., $$\frac{e_{AB}}{e_s} = \frac{L\omega}{R}$$

i.e., the ratio of the voltage across AB to the input voltage is equal to $\frac{L\omega}{R}$.

Magnification Factor

We have already seen that R is generally very much smaller than $L\omega$, and hence $\frac{L\omega}{R}$ is much greater than 1. That is to say, the voltage operating the receiver is much greater than the input voltage. In other words, the tuned circuit has resulted in a magnification of the voltage. The expression $\frac{L\omega}{R}$ is the amount by which the input voltage has been magnified and is known as the MAGNIFICATION FACTOR of the coil. We shall employ m as a shorthand notation for the magnification factor of a coil. In the expression $\frac{L\omega}{R}$, L is in henries, R is in ohms, and ω is the angular frequency of the current, and equals 2π times the frequency in cycles per second. In the case of coils used in medium-wave tuning circuits, m usually has a value between 100 and 250, the actual value depending on both the construction of the coil and the effect of the circuit in which it is connected.

Note that, since we are concerned with the condition of the circuit *at resonance*, we may write ω_0 for ω, and we may then replace $L\omega$ by $\frac{1}{C\omega}$, $\left(\text{at resonance } L\omega = \frac{1}{C\omega}\right)$ thus giving :—

$$m = \frac{L\omega_0}{R} = \text{(also) } \frac{1}{RC\omega_0}.$$

Also, $$\omega_0 = \frac{1}{\sqrt{LC}}$$

and hence $\frac{L\omega_0}{R}$ becomes

$$\frac{L}{R} \times \frac{1}{\sqrt{LC}} \text{—}i.e., \frac{1}{R}\sqrt{\frac{L}{C}}$$

which is yet another way of expressing the coil magnification factor.

Let us find the magnification factor of a coil of inductance 250 mH. employed in a medium-wave tuning circuit. If we find the value of m corresponding to wavelengths of 300, 400, 500 and 600 metres, this will be sufficient to show how m varies with wavelength. These wavelengths correspond to frequencies of 10^6, 7.5×10^5, 6×10^5, and 5×10^6 cycles per second, and hence the angular frequencies are $2\pi \times 10^6$, $2\pi \times 7.5 \times 10^5$, $2\pi \times 6 \times 10^5$, and $2\pi \times 5 \times 10^5$, *i.e.*,

$$2 \times 3.14 \times 10^6 = 6.28 \times 10^6$$
$$2 \times 3.14 \times 7.5 \times 10^5 = 4.71 \times 10^6$$
$$2 \times 3.14 \times 6 \times 10^5 = 3.77 \times 10^6$$

and

$$2 \times 3.14 \times 5 \times 10^5 = 3.14 \times 10^6$$

The H.F. resistance of the coil depends on the frequency of the signal—*i.e.*, on the wavelength—and we shall take the following H.F. resistance values as typical of a well designed coil wound with Litz wire. The additional resistance introduced by the effect of the valve with which the coil is used has been taken into consideration.

Wavelength (metres).	H.F. Resistance (ohms).
300	10·0
400	6·0
500	4·0
600	3·0

Thus we have :—

$$m = \frac{250 \times 6.28 \times 10^6}{10^6 \times 10} \text{ at 300 metres}$$

i.e.,

$$m = 157 \text{ at 300 metres.}$$

Repeating the calculation for the other wavelengths, we obtain the following results :—

Wavelength (metres).	Coil Magnification Factor (m).
300	157
400	196
500	236
600	262

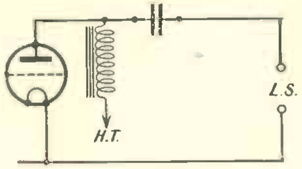
Thus we see that an induced signal voltage of 1 millivolt is magnified by the coil to 157 millivolts at 300 metres, and to 262 millivolts at 600 metres. For a given signal strength, therefore, the receiver response improves as the wavelength is increased. With another type of coil the value of m will, of course, increase at a different rate.

HOW TO MATCH LOUD SPEAKERS TO THE OUTPUT STAGE

By L. D. MACGREGOR

THE main purpose of matching the loud speaker to the output stage is to obtain the best quality of reproduction together with the maximum permissible amount of power consistent with that quality.[1]

In order to achieve this aim there are various items which must be taken into consideration, and it is as well to deal with these severally before discussing the use which will eventually be made of them.



(a) Plain Choke-fed Output

Fig. 1A.—METHODS OF COUPLING LOUD SPEAKER TO OUTPUT STAGE.

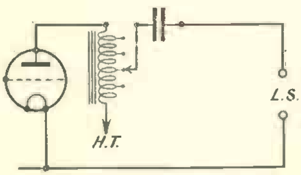
Showing plain choke-fed output.

The Impedance of the Speaker

The impedance of a loud speaker is a quantity which varies with frequency, and, as it is made up of the effective resistance, inductance and capacity of the unit in question, it is obvious that although this quantity may be taken into account when determining the load applied to the output stage it must be remembered that the sound or acoustic output from the loud speaker is not entirely dependent upon the impedance. There may, in fact, be a greater output at a high than at a low impedance and *vice versâ*, due to the diaphragm and other constructional details. It is not proposed to deal with the measurement or derivation of loud speaker impedance as this is a matter which has been ably dealt with elsewhere.[2]

The Effect of the Valve on the Results

The valve must work harmoniously with the loud speaker if the best results are to be obtained, and in arriving at this state of affairs lies one of the most important factors in matching, which will be dealt with as we proceed.



(b) Tapped Choke-fed Output

Fig. 1B.—METHODS OF COUPLING LOUD SPEAKER TO OUTPUT STAGE.

Showing tapped choke-fed output.

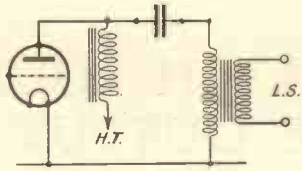
The Method of Coupling

The method of coupling the loud speaker to the output stage must be taken into account when endeavouring to match the speaker to the output. The various methods of coupling are illustrated in the accompanying sketches (Fig. 1, *a*, *b*, *c* and *d*). In the case of resistance, choke and choke-transformer outputs it will be observed that the resistance or choke acts as a shunt across the speaker impedance—or, in the case of transformer, the speaker impedance referred to the primary winding—and due allowance will have to be made for this effect (see Figs. 12 and 13).

The Power Handling Capacity of the Loud Speaker at Various Frequencies

If we take a moving-coil loud speaker, and, keeping the power input constant, whilst varying the frequency, measure the movement of the diaphragm at various frequencies, it will be found that the greatest movement occurs at the lower frequencies—the amount of movement progressively decreasing as the frequency is raised. As there is a limit to the permissible movement of the diaphragm there must obviously be a limit to the amount of power—at a given low frequency—that the unit will stand. Beyond that it will be necessary to reduce the power at the lower frequencies if "rattling," etc., are to be obviated.

It has been estimated by Dr. N. W. MacLachlan that, to radiate a sound or acoustic output of 1 watt at 50 cycles from an 8-inch cone, the amplitude of movement of the cone would be about 1·3 cm.—over ½ inch. In this respect the efficiency of the loud speaker, $\frac{\text{Sound output}}{\text{Energy input}}$, will have to be considered, and, assuming this to be 6 per cent., the input required for the above sound output would have to be 16·7 watts. From this we may estimate, very roughly, that a good speaker, to handle 5 watts input, at the frequency of 50 cycles, should possess a free cone movement—forwards or backwards—of ½ cm. As the frequency increases the amount of movement required to produce the same amount of sound energy decreases, hence the reason for checking this at the lower frequencies.



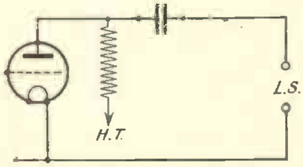
(c) Choke Coupled Transformer Output

Fig. 1C.—METHODS OF COUPLING LOUD SPEAKER TO OUTPUT STAGE.

Showing choke-coupled transformer output.

A General Rule

Further, if we consider an orchestral item, it will be obvious that, shall we say, the "average amplitude value" is about a tenth of the "amplitude value" on loud passages and the last valve and the speaker must be capable of handling these momentary heavy loads if distortion and "rattling" are to be entirely eliminated. As a general rule, in domestic use, the output stage is rarely large enough to warrant considering this point, but when outputs of, say, over 5 watts are contemplated, this factor will have to be taken into consideration.



(d.) Res.-Capacity Coupled Output

Fig. 1D.—METHODS OF COUPLING LOUD SPEAKER TO OUTPUT STAGE.

Showing resistance-capacity coupled output.

The Frequency Characteristic of the Receiver or Amplifier

By this is meant the manner in which different frequencies are amplified with regard to others. A perfect amplifier would amplify all frequencies equally. Owing to the necessity for very selective tuning, in certain instances the frequencies above 5,000 cycles per second are considerably reduced in consequence of the sharply tuned circuits. Further, it is not an easy matter to construct an amplifier which will give a good frequency characteristic from 50 to 10,000 cycles per second.

In view of this there is little use in considering frequencies of from 5,000 to 10,000 cycles if the ratio in which they are present with regard to the other frequencies is very small, as would be the case in a receiving set with 5 kilocycles separation possessing no compensating device.

On the other hand, many intervalve coupling devices are now available which give extra amplification at the higher frequencies whilst maintaining a fair amount of bass and, if it is known that the receiver is so equipped, it is worth while using a good loud speaker and well matching it to the output. As a general rule it may be considered that the main output lies between 100 and 4,500 cycles, the output level "tailing off" above 4,500 and below 100 cycles. With an equipment of good quality the main output will extend down to 50 cycles and possibly below and up to 6,000 cycles, and possibly above this figure.

VALVES—THEIR PART IN MATCHING

In order to comprehend the part played by the valve in the course of matching valve and loud speaker it is absolutely essential that consideration be given to the valve characteristic curves.

Grid Volts—Anode Current Curves

Nearly everyone is familiar with the average valve curves known as the grid volts-anode current curves wherein the grid volts are shown on the horizontal scale and the anode current on the vertical scale. These curves were used for the purpose of finding the correct bias for different values of anode voltage the custom being to bias the valve to the mid-point of the straight portion of the curve.

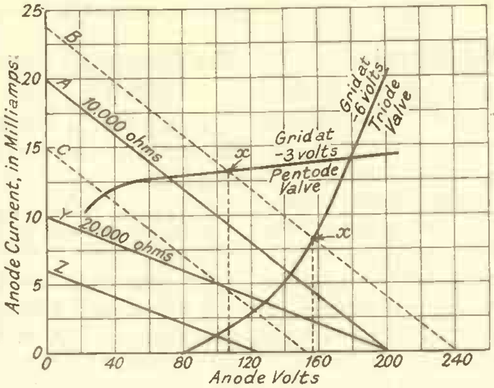


Fig. 2.—Typical Anode Current-anode Volts Curve for a Pentode and a Triode.

Anode Volts — Anode Current Curves

There is another set of curves known as the anode volts-anode current curves, showing the variation of anode current with anode volts for various values of grid bias. It is from these curves that the output and load resistance values are obtained.

These curves are shown in Figs. 2, 3 and 4.

How to Use the Curves

Before dealing with the actual sets of curves in Figs. 3 and 4 let us consider Fig. 2. This shows a typical anode current-anode volts curve for a pentode and for a triode. The sloping lines denote resistance values and it will be observed that different values of resistance give lines of different slope. Thus the line joining 200 volts to 20 milliamps is equal to 10,000 ohms — A, and the line joining 200 volts to 10 milliamps is equal to 20,000 ohms—Y. The resistance value is easily arrived at, being equal to $\frac{\text{volts}}{\text{current}}$. Thus $\frac{200}{\cdot 01} = 20{,}000$ ohms.

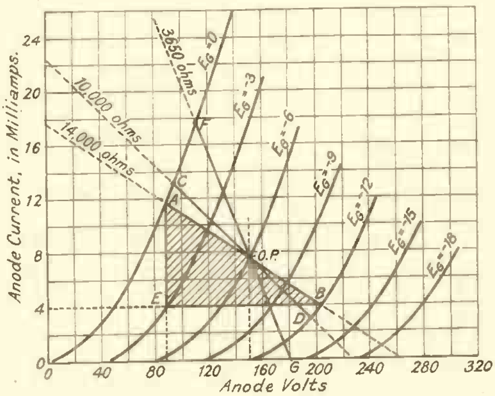


Fig. 3.—Anode Current-anode Volts Curves for a Mazda P220 Valve.

Lines which are parallel have the same resistance value. A, B and C are equal to 10,000 ohms each, and Y and Z are each equal to 20,000 ohms. This point will be of use to us when we consider the other valve curves. It will be noticed that line B cuts the triode and pentode curves at —X. This shows us what volts we would obtain on the anode of each of these valves if we connected a resistance of 10,000 ohms in series with the valve and had an H.T. supply of 240 volts.

If we drop a perpendicular line down to the base line from the point of intersection —X, it will indicate the H.T. voltage on the anode of the valve. Thus, in the case cited, the pentode would have an anode voltage of 107 volts and the triode an anode voltage of 157, assuming a 10,000 ohm resistance in the anode of each and an applied voltage of 240.

Providing a set of anode current-anode volts curves are available this method can be applied to any valve to determine its anode voltage.

What is the "Optimum Load?"

The "optimum load" is the name given to that value of load imposed on the valve which allows for a distortion limit of 5 per cent. for a second harmonic or a third harmonic distortion. Truthfully speaking, the optimum load is what you care to make it, but the above definition is the generally accepted one.

How the Load Value is obtained

In Fig. 3 we have a set of anode current-anode volts curves for a Mazda P220 valve. The manufacturers give the figure of 10 m.a. as maximum anode current at 150 volts on anode, and, from an inspection of the grid volts-anode current curves for the same valve we find this corresponds to 5·25 volts negative bias. As the nearest value to this is —6 volts on the curves we have at hand, we will choose this figure for our working bias voltage for the purpose of illustrating how the values of load resistance are obtained. Now, if we draw a vertical line

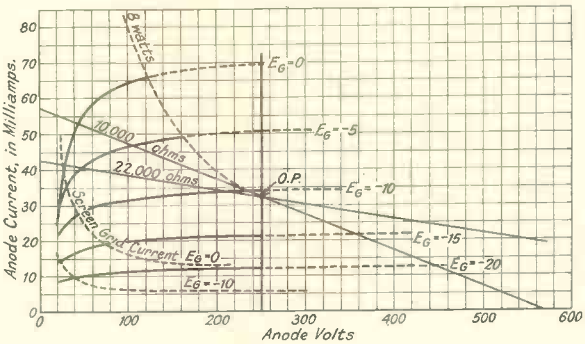


Fig. 4.—Anode Current-anode Volts Curves for an Osram M.P.T.4 Valve.

from our anode voltage scale at 150 volts, where this line cuts the curve at —6 volts will give us our operating point—OP.

Any line passing through this point and cutting across the other curves may be termed a " load line " and will correspond to a resistance (see Fig. 2). Since we have seen from Fig. 2 that lines parallel to each other have the same resistance, we can draw a line of a given resistance value at one end of the scale and then draw one parallel to this through O.P. for that resistance value.

On the chart in Fig. 3 three such lines are shown passing through OP. One FG = 3,650 ohms, one CD = 10,000 ohms, and one AB = 14,000 ohms.

Now the percentage distortion will vary in each case. What is the percentage distortion value for these three load lines, and how is it obtained? What is the power output for these load lines?

The Percentage Distortion and the Power Output

The formula employed for arriving at the percentage second harmonic distortion is a very simple one and is as follows:

$$\frac{\frac{1}{2}\,(\text{I max.} + \text{I min.}) - I_{OP}}{\text{I max.} - \text{I min.}} \times 100\%.$$ [3]

In our case we biassed the valve at —6 volts, and the steady current at this operating point, which we will call I_{OP} was equal to 7·5 milliamps. If we allow an input swing which will reduce the grid voltage to zero we can easily see that its value will be 6 volts (peak voltage). The positive half-cycle will reduce the grid volts to zero and the negative half-cycle will increase it to —12 volts. When the grid is at its lowest point—zero in our case—the anode current will be at a maximum and the value for the case under consideration will be 11·8 m.a. This is I max.

Similarly at the other end of the cycle the grid will be —12 volts and the value of anode current for this is 4 milliamps—this is I min., and these are the values to insert in the formula.

Now 6 volts peak swing is equal to 4·24 volts swing r.m.s., and this is the input voltage which must not be exceeded, otherwise the grid of the valve would become positive and grid current would flow. Taking our three load lines and working out the percentage distortion we obtain the following table:—

Line.	Value.	Per cent. Distortion.
AB	14,000 ohms	5·1 per cent.
CD	10,000 ,,	1·3 ,,
FG	3,650 ,,	12·5 ,,

How to Find the Power Output

Before we can decide anything further we shall require to know the power output for these lines. Now if we draw a perpendicular line from where the load line cuts the curve $Eg = 0$ at A and a horizontal line from where it cuts the curve -12 at B, we shall find that they enclose a triangle, AEB, and the power output is proportional to the area of this triangle. If we take the values of the sides of the triangle—AE in milliamperes and EB in volts—multiply these together and divide the result by 8 we obtain the power output in milliwatts.

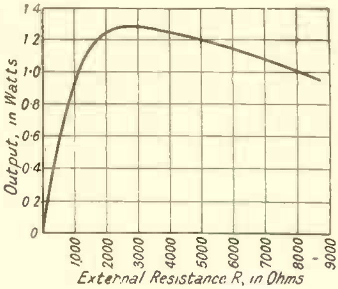


Fig. 5.—A Power Output Curve for a Super-power Triode Valve for various External Resistances.

In the case under consideration we have AE = 11·8 – 4 m.a. = 7·8 m.a., EB = 204–88 volts = 116 volts. Then the power output is equal to $\frac{116 \times 7{\cdot}8}{8} =$ 113·3 milliwatts. For our different values of load resistance we have, therefore, the following results.

Input to Valve	Load Line	Res. Value	% Distortion	Power output
		Ohms.	%	Milliwatts
4·24 volts r.m.s.	AB	14,000	5·1	113
	CD	10,000	1·3	115·5
	FG	3,650	12·5	128·6

From which we observe that the load value for maximum power is also the value for maximum distortion. Now, if we desire power we will use a load such as F.G., whereas if we desire quality a load such as CD is obviously the better one. It will also be observed that the load value giving the lowest percentage of distortion is over twice the value of the A.C. resistance of the valve, which is given as 3,700 ohms.

The Case of a Pentode

This permits of exactly similar treatment as in the case of a triode. There is one fundamental difference, and that is in the dangerously high voltage it is possible to develop with the pentode. In the case of the pentode, whose curves are shown in Fig. 4, the makers recommend that the load resistance does not exceed 10,000 ohms. Two load lines are shown on this set of curves, one for a 10,000-ohm load and one for a 22,000-ohm load.

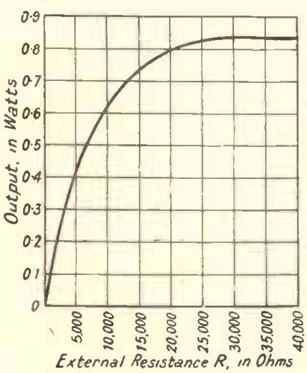


Fig. 6.—Power Output Curve for a Pentode.

Why the Load Resistance should be kept low

In the latter case the voltages developed across this load might easily reach the value of 800 or 900 volts and cause serious damage. Hence the reason for keeping the load resistance low.

In Fig. 2 we have curves of power outputs for different resistance values of load for a pentode and triode. Note how the power increases with the load in the case of the pentode.

Breaking the anode circuit with the H.T. supply connected is likely to generate these high voltages and to cause damage.

Shunting a Resistance across the Speaker Output

When we consider the fact that the impedance of reed speakers rises with frequency (Fig. 8), and that of electrostatic speakers rises with decrease of frequency, it will be obvious that some sort of device will have to be incorporated to keep the load on the valve within safe limits. This may be accomplished by shunting a resistance across the speaker output (Fig. 7 (*a*)), but has the disadvantage in the case of a reed speaker of causing some loss at low frequencies, which generally can ill be afforded.

Why a Condenser is added in Series with the Resistance.

To compensate for this a condenser is usually added in series with the resistance, as in Fig. 7 (*b*). The condenser passes the higher frequencies more readily than the low ones and as the frequency increases the combined impedance of condenser and resistance decreases, tending to keep the load constant.

The impedance of a condenser and resistance in series, Z_{CR}, is equal to

$$\sqrt{R^2 + \left(\frac{1}{2\pi fc.}\right)^2}$$

and this is shunted across the speaker impedance. The values of C and R will vary with the speaker impedance, but as a rule $\frac{1}{2\pi fc}$ is made equal to the optimum load at 1,600 cycles and R is so chosen that the combined effect of C and R in shunt across the speaker brings the anode load on the valve back to normal.

Suitable values for pentodes are :—

Pentode Opt. Load	C.	R.
Ohms.		Ohms.
9,000 to 10,000 (mains pentode)	·01	7,500/10,000
7,500 to 9,000	·01	7,500/10,000
20,000 to 30,000	·001	up to 50,000

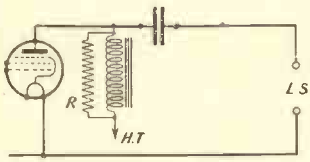
If R is chosen as being equal to one and a half times optimum load resistance and the value of C as described above, the results will be a close approximation to the requirements.

OUTPUT VALVES AND THEIR SUITABLE OPTIMUM LOAD RESISTANCES

Valve.	Anode H.T. Volts.	G. Bias Volts.	Optimum Load. Ohms.	A.C. Resistance. Ohms.
Cossor :				
215P .	150	7·5	9,000	4,000
220P .	150	9·0	9,000	4,000
230PA .	150	4·5	9,000	4,000
230XP .	150	18·0	3,500	1,500
625P .	200	12	6,000	2,500
41MP .	200	7·5	3,000	2,500
41MXP	200	12·5	2,000	1,500
220PT .	150	9·0	7,500	—
220HPT	150	4·5	17,000	—
230PT .	150	15·0	10,000	—
MP/PEN	250	12	10,000	—
Marconi & Osram :				
P215 .	150	12	12,000	5,000
LP2 .	150	6	7,100	3,900
P2 .	150	10·5	4,500	2,150
PX4 .	250	34	3,200	830
ML4 .	200	8·5	7,000	2,800
PT2 .	150	4·5	17,000	—
MPT .	250	11·0	8,000	—
DPT .	200	10	8,000	—
Mullard :				
PM2A .	150	6·0	7,000	3,600
PM202 .	150	12·0	3,700	2,000
AC064 .	200	21·0	5,000	2,000
AC044 .	200	32·0	2,500	1,150
104V .	200	12	6,000	3,000
PM22A	150	4·5	15,000	—
PM22 .	150	10·0	8,000	—
Pen 4V	250	10·0	8,000	—
Mazda :				
P220 .	150	7	9,500	3,700
,, .	120	4·5	10,000	—
P220A .	150	14	4,100	1,850
,,	120	10	4,300	—
P240 .	150	14	5,600	1,900
,,	120	4·5	5,000	—
AC/P .	200	15	6,000	2,650
AC/P1 .	200	30	5,000	1,450
Pen 220	150	4·5	17,000	Screen 150v
,,	120	3·0	23,000	,, 105v
Pen 220A	150	9	7,500	,, 150v
,,	120	7·5	9,000	,, 120v
A.C. Pen	250	10	10,000	,, 200v
,,	200	10	9,000	,, 200v
DC Pen.	250	10	10,000	,, ,,
DC2 Pen	250	10	10,000	,, 200v
DC2 Pen	200	10	9,000	,, ,,

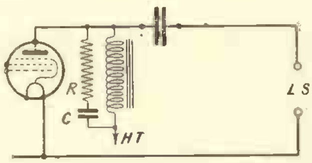
Importance of Anode Volts—Anode Current Curves

The use of the anode volts-anode current curves is the only method whereby the load resistance, percentage distortion and power output may be arrived at without costly laboratory apparatus and the experimenter who wishes to check results for himself will find it well worth the trouble to adopt the procedure described. It will be observed that the power output, the percentage distortion, the load resistance and the grid swing of the valve are, as it were, interdependent. For those who do not care to go to the trouble of working these particulars out most manufacturers give the value of the "optimum load" (for 5 per cent. distortion) in the leaflets in the valve container. These figures are given for a definite value of H.T. voltage and bias voltage, and hold good for these voltages. Others give a set of curves showing the anode current, grid bias and appropriate load resistance to use for different values of H.T. voltages. A table of suitable load resistances for various valves is given on the previous page.



(a) Pentode Output Circuit with Limiting Load Resistance R

Fig. 7A.—Pentode Output Circuit with Limiting Load Resistance (R).



(b) Similar Circuit to (a) but with Condenser C, to reduce Loss at the Lower Frequencies

Fig. 7B.—Pentode Output Circuit with Condenser (C) to reduce Loss at the Lower Frequencies.

Matching Speaker to Valve

Assuming that we have arrived at the best load or "optimum load," for our valve we have to consider the matching of our speaker to it. Now, no speaker has a constant impedance, therefore we will have to match it at one value. This applies particularly to reed speakers where the impedance rises with frequency. If we match the speaker at a frequency where its performance is least we can level up the sound output thereby. This, however, can only be ascertained by experiment. As a general rule reed speakers are matched to their impedance at 256 cycles and if this is not known we shall find that we will not be far out if we multiply the speaker's D.C. resistance by two and match to this figure. Matching may be achieved with high resistance speakers by choosing a valve which has an "optimum load" equal to the speaker impedance, or nearly so.

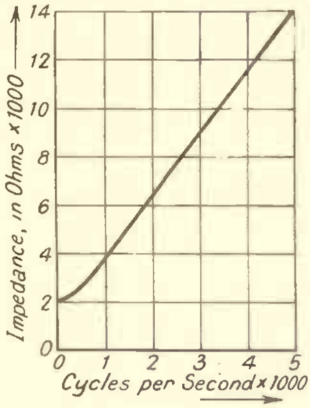


Fig. 8.—Graph showing Increase of Impedance with Frequency.

The impedance of the average reed speaker may be taken, for purposes of matching, as round about 4,000 ohms.

Electrostatic Loud Speakers

The average electrostatic speaker may be considered as being equal to 4,000 ohms for the purposes of matching, and this is the value of its impedance at 250 cycles. The larger electrostatic models have an impedance of about 2,000 ohms at the same frequency. Valves suitable for working these speakers should have an A.C. resistance of approximately 2,000 and 1,000 ohms respectively.

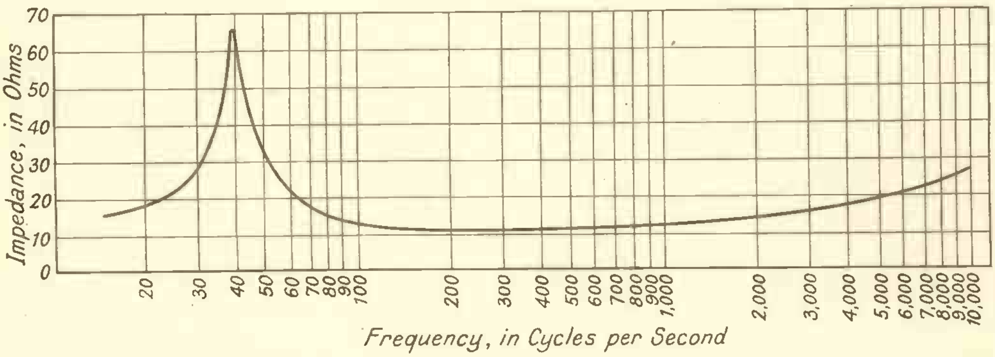


Fig. 9.—Impedance Curve of Low Resistance Moving-Coil Loud Speaker.

Inductor Loud Speakers

These are as a rule best considered as having an impedance of 2,000 ohms, and if this value is adopted the results will be very pleasing.

Moving-Coil Loud Speakers

There are two varieties—one with no transformer and the other with. The impedance value may be obtained from the makers, but should this not be practicable the impedance may be considered as equal to from one and half to two times the D.C. resistance of the moving speech coil, and they may be matched by choosing a suitable ratio of transformer. Incidentally, this rough and ready rule of arriving at the impedance by multiplying the D.C. resistance by one and half to two *does not* apply to transformers. The average impedance value of low resistance speakers ranges between 4 and 20 ohms.

In Fig. 9 we have an impedance curve of a low resistance moving coil speaker, whose coil D.C. resistance was about 7 ohms. If power was desired the speaker would be best considered as being of 10 ohms impedance, but rather better quality would be obtained by considering its average impedance as being 14 ohms. This would tend to improve the upper and lower register.

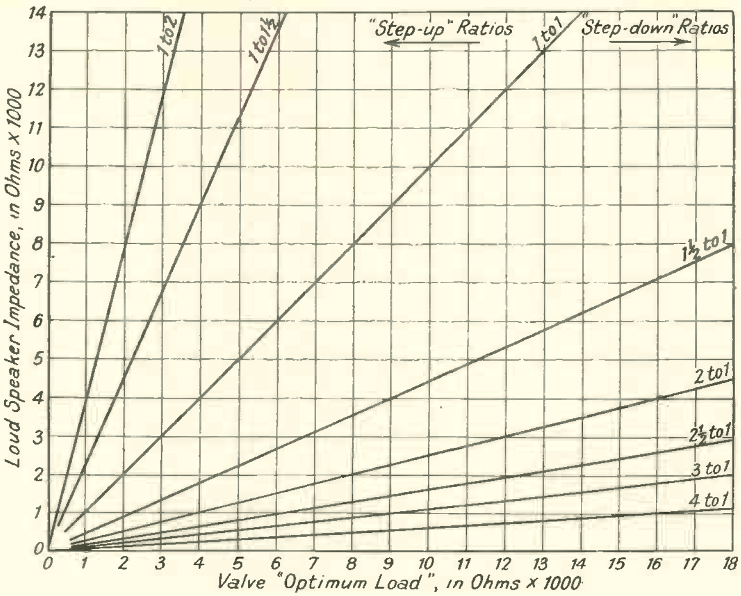


Fig. 10.—TRANSFORMER RATIOS FOR MATCHING LOUD SPEAKER TO VALVE.

THE OUTPUT TRANSFORMER

Now if our valve has an "optimum load resistance" of 5,000 ohms and our speaker is an Igranic moving coil speaker with an impedance of 16 ohms, what do we do? We cannot connect the speaker to the valve in the ordinary way because the values are out of all proportion. We must use a device that will transfer the speaker load to the valve and at the same time make it equal to the valve optimum load. Such a device is an output transformer and the load is made equal to the "optimum load" by choosing the right ratio of one winding of the transformer to the other winding.

The Correct Transformer Ratio

In the case of a single valve output the ratio is obtained by dividing the optimum valve load by the speaker impedance and taking the square root of the result :—

Transformer ratio =

$$\sqrt{\frac{\text{“ Optimum ” valve load}}{\text{Speaker impedance}}} \quad . \qquad (1)$$

For two valves in push pull :—

Ratio =

$$\sqrt{\frac{2 \times \text{“ Optimum ” load of one valve}}{\text{Speaker impedance}}} \qquad (2)$$

In this case the valves are virtually in series as far as load is concerned.

For any number of valves in parallel where the number is N :—

$$\text{Ratio} = \sqrt{\frac{\text{"Optimum" load of one valve} \div N}{\text{Speaker impedance}}} \quad (3)$$

For valves in parallel push-pull where N is the total number of valves :—

$$\text{Ratio} = \sqrt{\frac{2 \times \text{the "Optimum" load of one valve} \div \frac{N}{2}}{\text{Speaker impedance}}} \quad (4)$$

Formula (1)

Question.—A low-resistance moving-coil loud speaker of 16 ohms impedance is required to be coupled to a valve whose "optimum load" we have decided is 5,000 ohms. What is the required transformer ratio ?

Answer.—This may be easily arrived at by Fig. 11. Read off 16 ohms on the left-hand vertical scale. Take an imaginary line across the chart by holding a rule parallel to the line which extends across the chart from 15 ohms. Find the vertical line which corresponds to valve "optimum load" of 5,000 ohms. Where this line meets the rule, or what is academically known as "the point of intersection," will be found to lie either on, near to, or between one or other of the lines radiating across the chart from the zero at the left end. Choose the nearest line, this will have the desired ratio marked on it. Thus, in this case, 5,000 ohms valve "optimum load" and 16 ohms loud speaker impedance have their "point of intersection" nearest the sloping line marked 18 to 1. This gives the ratio as 18 to 1 "step-down," so that a transformer having this ratio and connected to a 16-ohm speaker would behave as if it were 5,000 ohms impedance—the speaker load having been, as it were, multiplied up by the transformer. Alternatively we can work this out :—

Required ratio =

$$\sqrt{\frac{5{,}000}{16}} = \sqrt{\frac{1{,}250}{4}} = \sqrt{312 \cdot 5} = 17 \cdot 67.$$

The nearest whole number to 17·67 is 18, which is given by the chart.

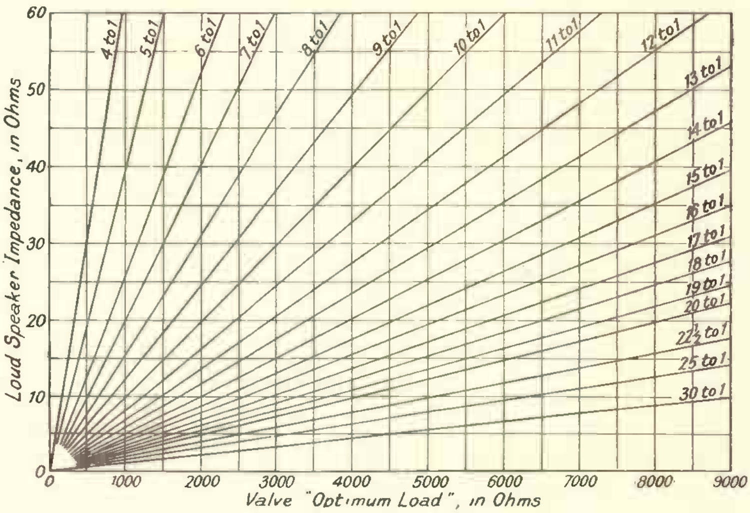


Fig. 11.—Transformer Ratios for Matching Loud Speaker to Valve.

Formula (2)

Question.—If each valve had the same "optimum load" as previously, viz., 5,000 ohms, and the same 16-ohm speaker was to be used with two of these valves in push-pull, what ratio of output transformer would be required ?

Answer.—The valves are back to back and their load impedances are therefore virtually in series. Therefore, from Formula 2, we have :—

Ratio required =

$$\sqrt{\frac{2 \times 5{,}000}{16}} = \sqrt{625} = 25.$$

This is not on the chart. The chart could be extended proportionately to cover valve "optimum loads" of 10,000 ohms. There is another way of arriving at the result, however.

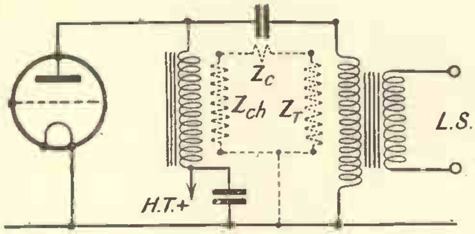


Fig. 12.—EQUIVALENT IMPEDANCES OF OUTPUT CIRCUIT.

Z_{ch}, impedance of choke; Z_c, impedance of coupling condenser (generally negligible); Z_T, impedance of speaker referred to transformer primary (shown dotted).

Our problem is $\sqrt{\frac{2 \times 5{,}000}{16}}$, which is equal to $\sqrt{2} \times \sqrt{\frac{5{,}000}{16}}$.

We know from the chart what $\sqrt{\frac{5{,}000}{16}}$ is, and the square root of two is well known as 1·414. Therefore, if we multiply 18 by 1·414 we will obtain the answer. 18 × 1·414 works out to 25·482. Now the previous figure was not quite 18, therefore we can neglect the ·482, which leaves us with 25 to 1 as the required ratio.

Formula (3)

Question.—Two valves, connected in parallel, with "optimum loads" of 4,000 ohms each, are required to be matched to a loud speaker, the most suitable impedance of which, for general use, is given as 4,000 ohms. What method will be employed and how shall the speaker be matched?

Answer.—The valves are in parallel and their "optimum loads" likewise in parallel From Formula 3 we obtain :—

$$\text{Ratio} = \sqrt{\frac{4{,}000 \div 2}{4{,}000}} = \sqrt{\frac{2{,}000}{4{,}000}} = \sqrt{\frac{1}{2}}.$$

If we take $\frac{\sqrt{1}}{\sqrt{2}}$ we get $\frac{1}{1{\cdot}414}$. This will indicate a transformer or auto-transformer, where the 1·414 ratio winding is connected to the speaker and the 1 ratio winding to the outputs of the valves, giving a step-up ratio. A 1 to 1·5 transformer would meet the case, assuming a 1 to 1·414 transformer to be unavailable.

Formula (4)

Question.—Four similar valves are connected in parallel push-pull. Each valve has an optimum load of 8,000 ohms. It is required to match a 20-ohm moving-coil speaker to the output. What ratio transformer would be required?

Answer.—Clearly this indicates two sets of two valves in parallel operating in push-pull. Fitting the values given into the formula we obtain :—

$$\text{Ratio} = \sqrt{\frac{2 \times 8{,}000 \div \frac{4}{2}}{20}} = \sqrt{\frac{8{,}000}{20}} = \sqrt{\frac{400}{1}},$$

which gives us 20 to 1 as the required ratio.

Sources of Loss

Loss due to a bad frequency characteristic in receiver or amplifier. This can be checked by matching a good speaker to the receiver or amplifier, and should loss occur some compensation may be made by matching at a lower or higher frequency according to which part of the frequency scale the loss occurs in. The best method is to employ tone correction in the receiver or amplifier itself.

A method of compensation for low frequency loss, when working from a

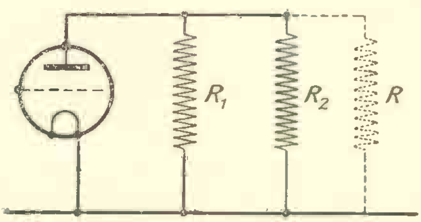


Fig. 13.—EQUIVALENT IMPEDANCES OF OUTPUT CIRCUIT.

Neglecting the impedance Z_c in Fig. 12, we have here: R_1 = impedance Z_{ch} at frequency F; R_2 = impedance Z_T at frequency F. These being in parallel are equal together to an impedance R (shown in dotted lines), which for optimum power should be equal to the "optimum load" for the valve.

pentode, by means of using choke output and choosing the coupling condenser so that it resonated with the speaker at low frequencies has recently been described.[5]

Sources of Loss in the Output Circuit

The shunting effect of the output choke is greater at low frequencies than at high frequencies, due to the fact that at the lower frequencies its impedance reaches its lowest values. The equivalent circuit is shown in Fig. 12 and Fig. 13.

The output choke impedance is virtually in shunt across the speaker load, if we consider the coupling condenser impedance to be negligible. Fig. 13 shows the equivalent circuit where the choke impedance and the speaker impedance are shown as resistances R_1 and R_2 in parallel and equal to a value R, where $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$, which, to secure optimum power, should equal the optimum load. If we consider the effect of R_1 shunted across R_2 as causing a loss, which will vary with the ratio of R_1 to R_2, this loss can be expressed as a percentage loss of value of R_2 and a table of such percentage loss is given for different ratios of R_1 to R_2. It is surprising to note how much larger R_1 has to be in order to keep the loss down.

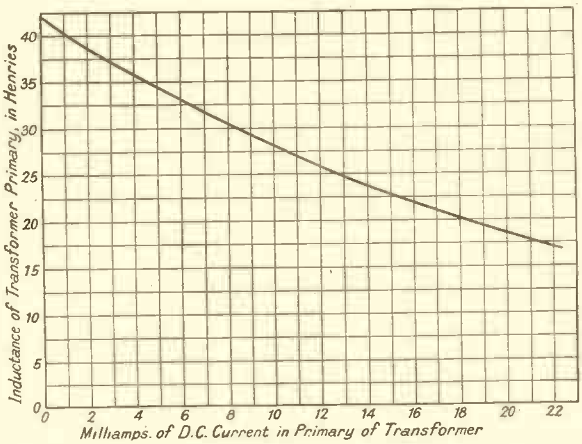


Fig. 14.—Inductance Curve of Output Transformer for Feeding Low-Resistance Moving-Coil Loud Speaker.

Taken on A.C. Bridge with constant supply of 2 volts A.C. (R.M.S., 50 cycles) across bridge.

Actually, in practice, these percentage losses would be hardly distinguishable to the ear and one may be tempted to neglect them, but it must be remembered that a number of small losses will eventually total up to a considerable figure.

Chok -fed Transformer Coupling

In the case of choke-fed transiormer coupling the ratio of the transformer used may be so chosen as to effect the necessary compensation for loss due to these causes

As a general rule choke-coupled output is adopted for one of the following reasons :—

(*a*) To save loss of volts on anode as in the case of reed speakers.

(*b*) To stop direct current flowing in the speaker or speaker transformer windings as in the case of a reed speaker or a high-resistance moving coil, and in the case of heavy anode currents when a low-resistance transformer-coupled speaker is used.

(*c*) Where extension leads are fitted and D.C. is to be kept from them.

If we consider our table of losses (below) we find that if R_1 is nineteen times R_2 the loss is only 5 per cent. Therefore if at, say, 50 cycles our transformer primary has an inductance of 2 henries we shall require a choke of $2 \times 19 = 38$ henries if we wish to keep the loss down to 5 per cent. If

Table of Percentage Loss of Value of R_2 for Different Values of R_1.

Ratio of Value of R_1 to Value of R_2	Percentage loss of R in value
Where R_1 = Infinity .	0 per cent.
„ R_1 = 9,900 times R_2	1 „
„ R_1 = 49 „ R_2	2 „
„ R_1 = 33 „ R_2	3 „
„ R_1 = 24 „ R_2	4 „
„ R_1 = 19 „ R_2	5 „
„ R_1 = 9 „ R_2	10 „
„ R_1 = 5·6 „ R_2	15 „
„ R_1 = 4 „ R_2	20 „
„ R_1 = 3 „ R_2	25 „

we allow a loss of 10 per cent. we would require $2 \times 9 = 18$ henries. We have assumed that the coupling condenser impedance is negligible. Taking the 10 per cent. loss case, if the speaker load transferred to the primary of the transformer had been 4,000 ohms with a 20 to 1 transformer and a 10-ohm speaker, then when it was coupled up to the choke the load would be 3,600 ohms, and if it were desired to match the speaker to this load the ratio would have to be changed to 19 to 1.

If it were desired to maintain the load figure at about 4,000 ohms the transformer ratio could be increased to 21 to 1 and this would compensate at this frequency. Further, we must consider the valve curves in order to decide, as at the lowered load the power may increase and so automatically compensate for loss.

Loss due to the Speaker Coupling Transformers

Loss may occur due to this transformer possessing a bad frequency characteristic curve. Loss may again occur due to the inductance varying widely with polarising current. In Fig. 14 we have an inductance curve of the transformer supplied with a popular make of moving-coil loud speaker. This curve shows the variation of the inductance with polarising current. When considering the polarising current value it is well to remember that there will be a superimposed A.C. current when the valve is working.

If we take a valve which passes an anode current of 11 milliamperes having an undistorted output of 350 milliwatts at an optimum load of 5,600 ohms, we find, by calculation, that the current in that load will be approximately 8 milliamperes A.C. When the valve is delivering its maximum output this current will be superimposed upon the 11 milliamperes D.C. Will the inductance of the transformer be unnecessarily lowered at this figure? In the case under consideration—No. In like manner, due to lowering of the inductance, the speaker load referred to the primary may be lessened.

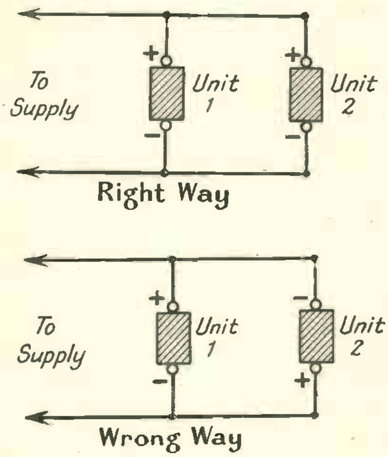


Fig. 15—The Right and Wrong Way of Connecting Two Loud Speakers in Parallel.

Loss caused by Secondary having too high a Resistance

Loss will again occur if the secondary of the transformer has too high a resistance relative to the speaker which is connected to it. The loss is easily computed, being equal to I^2R, where I is the current flowing and R the A.C. resistance of the winding at the frequency under consideration.

Loss due to Magnetic Leakage

Another source of loss in transformers is due to magnetic leakage, which causes in turn high note loss. It is not possible to check this without laboratory equipment. Providing that a primary inductance of not too high a value be employed this may, reasonably safely, be neglected. The leakage inductance acts as if it were outside the transformer and resonates with the self capacity of the transformer in, as it were, a series circuit. This generally occurs at a high frequency and the energy which should be transferred is practically by-passed. Keeping the inductance down means keeping the turns down, and with it the self capacity. If the inductive reactance, $2\pi fL$, is from one and a half to two times the "optimum load" resistance value all should be well. The frequency, f, should be the lowest to which the speaker is desired to respond, and may be taken on an average as 50 cycles for moving-coil speakers.

Two or More Speakers from One Set

If two or more speakers are connected to the same output it will be necessary to consider the sum total of the effect of them, and to insert a compensating device when one or the other is withdrawn.[6] This should preferably take the form of an inductance in series with a resistance, and it may be necessary to experiment with various values to achieve the best result. At first sight it may seem that an inductance equal to that of the speaker which was removed, together with a resistance of similar value to the speaker resistance, would suffice, but such is not the case as the effective resistance of a reed speaker rises with frequency.

Use a Resistance

It will be necessary, therefore, to use a resistance of from 10,000 to 25,000 ohms in series with an inductance of from 3 to 5 henries in value to replace a reed speaker which had been connected in parallel with another speaker. This combination will not be a perfect substitute, but will function better than a plain resistance. A moving-coil speaker may be satisfactorily replaced by a resistance equivalent to its impedance, and a condenser, with possibly a small amount of series resistance, may be used to replace an electrostatic speaker. The value of this condenser is best found by trial.

A Practical Tip when connecting Reed Loud Speakers

When connecting reed loud speakers in parallel connect the positive terminal of one to the positive terminal of the other, as shown in " the right way " in Fig. 15. Should the speakers be connected with the positive terminal of one to the negative of the other, as shown in " the wrong way " in Fig. 15, a peculiar effect may become apparent—perhaps I should say " defect " for " effect," because the quality will have altered and the result will not be pleasing. This is due to one speaker momentarily acting as a motor and then the other, and is similar to the effect known to electrical engineers as " hunting."

Similarly, when two moving-coil speakers are connected in parallel, it should be done so that at any given instant the movement of both diaphragms is in the same, and not in opposite, directions. This will prevent acoustic circulating currents. When the speakers are wrongly connected up the majority, if not all, of the bass register will disappear for the above reason.

Method of obtaining A.C. Volts and Current for the Optimum Load at Max. Undistorted Output

Undistorted output in watts = I^2R, where R is the load and I is the current in the load.

If the undistorted output is multiplied by the optimum load we have $I^2R \times R = I^2R^2$.

If the square root of this be taken we obtain IR, which gives the volts across the load.

The current may be computed by dividing the volts by the load resistance, thus, $\frac{I \times R}{R} = I$.

Example.—A certain valve has a rated undistorted output of 350 milliwatts for a load of 4,100 ohms—this being the optimum load for this valve.

I^2R = 350 milliwatts = ·35 watts.
R = 4,100 ohms.
I^2R^2 = 1,435.
$\sqrt{I^2R^2} = 37{\cdot}9$ = volts across R = IR.
$\frac{IR}{R} = \frac{37{\cdot}9 \times 10^3}{4{,}100}$ milliamperes = 9·25 m.a. (nearly) = I.

∴ The volts across the load will be 37·9 volts.

The current in the load will be 9·25 milliamperes.

If the output wattage was R.M.S. these figures will also be R.M.S. values.

Bibliography

1 N. W. MacLachlen, D.S.C., M.I.E.E. Articles dealing with Loud Speakers and Output Stage. *Wireless World*, July 11th, 1928; July 18th, 1928; August 8th, 1928; January 30th, 1929.

2 W. A. Barclay. " Loud Speaker Impedances." *Wireless World*, February 18th, 1931.

3 E. Yeoman Robinson (Ediswan). " Pentode and Power Output." *Wireless World*. July 23rd, 1930.

4 L. G. A. Sims, M.S.G. *Wireless World*, January 16th, 1929. (Curves 3 and 4 taken from article.

5 L. G. A. Sims, M.S.G. " New Output Circuit." *Wireless World*, June 29th, 1932

6 H. W. MacLachlan, D.S.C., M.I.E.E. " Two Speakers from One Output." *Wireless World*, September 23rd, 1932.

SAFETY AND PROTECTIVE DEVICES FOR RADIO CIRCUITS

By HARLEY CARTER

ALTHOUGH even the most powerful mains set, if carefully constructed from good quality components, and correctly operated, is as safe to use as any other domestic electrical device, there is always present the *possibility* of mechanical breakdown through accident, which may be followed by an electrical breakdown, and the chance of mistakes in connections, so that it is reasonable and wise to instal safety and protective devices to prevent or limit the damage to valuable apparatus in the event of mishap.

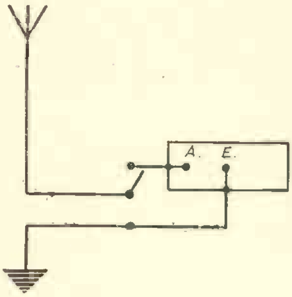


Fig. 1. — SIMPLE SINGLE-POLE-CHANGE-OVER SWITCH.

For connecting aerial direct to earth.

Main Classes of Protective Devices

Devices of this nature may be roughly divided into the following four classes :—

(1) Aerial and lightning protection.
(2) Fuses for circuit protection.
(3) Special insulating and isolating devices.
(4) Special switching devices.

AERIAL AND LIGHTNING PROTECTION

There have been a number of cases in which lightning has discharged through the aerial and has damaged or even wrecked a receiver. It is, therefore, a very sound policy to provide means for disconnecting the receiver from the aerial during thundery weather, or for safely discharging the aerial. This should always be done with an outdoor aerial, and it is also advisable to fit similar protection if an indoor aerial is led from the upper storey of a house to a lower floor by means of a down lead running outside the house.

Single-pole Change - over Switch

Many methods of achieving safety from lightning are available, differing in the degree of protection afforded. The simplest is a single-pole change-over switch, connected as shown in Fig. 1. With the switch in the upper position the aerial is connected to the aerial terminal of the set ; when the switch is thrown over to the lower position the aerial is connected to earth.

Double-pole Double-throw Switch

A somewhat more elaborate arrangement is shown in Fig. 2, where a double-pole double-throw switch is employed. In this circuit the switch, in the upper position, connects aerial and earth to their respective terminals on the set, while in the lower position the aerial and earth are connected together, the connections to the set being broken and the receiver being therefore completely isolated.

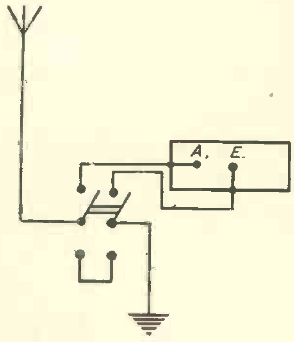


Fig. 2.—DOUBLE-POLE DOUBLE - THROW SWITCH.

This enables the set to be completely isolated from aerial and earth.

Installing Aerial and Lightning Protectors

Such devices, to be perfectly safe, should be installed outside the house. Two objections can be put forward in this connection. In the first place, a switch of the open, porcelain-base type, when exposed to the weather rapidly deteriorates, and the contacts made between the blades and jaws become of poor conductivity, leading to weak and noisy reception. Then it is highly inconvenient to leave the house during a thunderstorm in order to operate the lightning switch. Another point which must not be overlooked is the fact that the protection is only operative when the switch is thrown over, and damage is likely to occur if a storm arises while the set is in use.

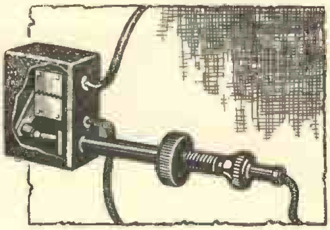


Fig. 3. — A SAFETY AERIAL SWITCH.

This consists of an ebonite lead-in tube with a metal push-rod running through it.

(*J. J. Eastick.*)

Protective Devices combined with Lead-in Tube

The first difficulty can be overcome by the use of a protected type of switch, but the modern solution lies in the combined switch and lightning discharger, many efficient types of which are produced by different manufacturers. Some of these devices are combined with a lead-in tube in such a way that, although the switch is located outdoors, it is operated from indoors. A good example of this type of switch is the "Eelex" safety switch illustrated in Fig. 3. It consists of an ebonite lead-in tube with a metal push-rod running through it. On the inner side, the rod terminates in an insulating knob having a socket for the reception of a plug connected to the aerial lead of the set.

How the Safety Switch Works

The end of the tube which projects outside the house is screwed into a weather-proof ebonite box containing a spring - operated switch which, when the push rod is pulled inwards, closes and connects the aerial to the earth wire. When, however, the rod is pushed outwards, the switch is moved to the off position. Two substantial metal plates with serrated spark gap are incorporated in the device, to act as a lightning discharger at all times when the set is connected.

In the "Pressland 'Cop' aerial control," which is also a safety lead-in tube, although no switch is fitted for earthing, a spark-gap discharger is contrived by an earthed metal collar surrounding, but not touching, the brass rod which forms the aerial connection, while the set can be disconnected from within by withdrawing a plunger. Incidentally, the partial withdrawal of this plunger alters the capacity of a small self-contained tubular condenser, and thus acts as a selectivity control.

Another Form of Safety Switch

Another interesting form of safety switch is made by A. F. Bulgin & Co. Ltd., and incorporates an enclosed switch which either connects the aerial to the set or to earth, a fuse which is always in circuit with the set, and a spark gap permanently connected across aerial and earth. The whole is mounted in a moulded cover with inspection windows and an indicating device which shows whether the aerial is connected to the set or to earth.

FUSES

Some form of fuse should be fitted to all

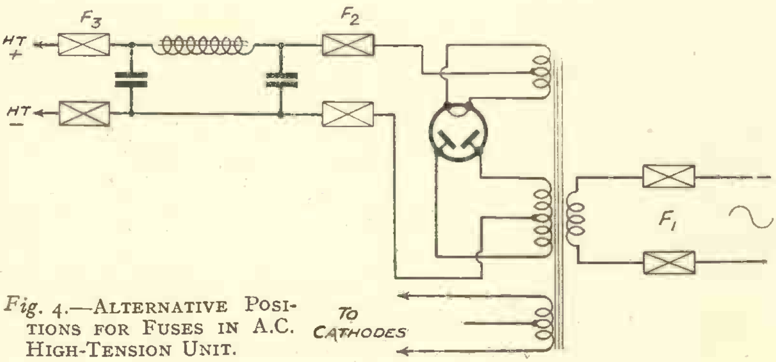


Fig. 4.—ALTERNATIVE POSITIONS FOR FUSES IN A.C. HIGH-TENSION UNIT.

radio apparatus operated from the electricity mains. There are also positions in which fuses should be installed in battery-operated receivers.

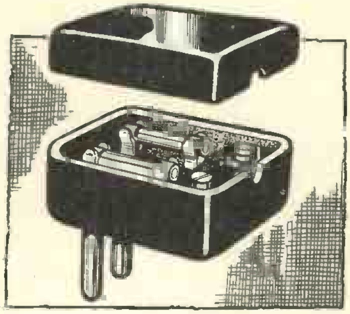


Fig. 5.—A 5-amp. B.S.S. Gauge Fused Plug Top with 1, 2, or 5 amp. D.P. Fuses. (*M. K. Electric Ltd.*)

Why a Separate Fuse is necessary in a Mains-operated Set

Dealing first with mains-operated sets, it will be obvious that if a receiver, consuming at the most 60 watts or so, is connected to the house circuit by one of the domestic wall plugs, the protection in case of a short circuit or earth within the apparatus is only that afforded by the fuse in the house circuit, which, in most instances is of 5 or even 10 amperes or more capacity. It is highly desirable to insert a much lighter fuse in the circuit of the set because the working current is seldom more than $\frac{1}{4}$ or $\frac{1}{2}$ ampere, and even a 5-ampere fuse would need an overload of over 1,000 per cent. before it would " blow." It is advisable, therefore, to fit a fuse rated at not more than 1 ampere within the mains set at the point where the mains are connected. It may also be wise to fit separate fuses on the output side of rectifier valves or metal rectifiers in order to protect the rectifier in the event of short circuit within the set. The rating of such fuses should, of course, be chosen with due regard to the output of the rectifier valve.

Types of Fuse-holder

Several standard types of fuse-holder are available. Double and single-pole open type baseboard fuseholders to accommodate metal-ended glass-enclosed tubular fuses are made by A. F. Bulgin & Co. Ltd., and similar double-pole holders can also be supplied by them with a detachable moulded protecting cover. This type is very suitable for any position in a mains receiver or radiogram, or may be mounted on the wall.

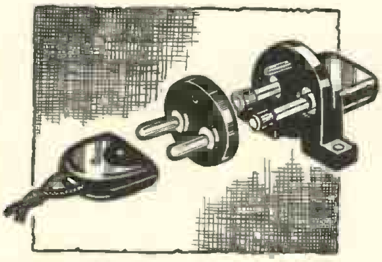


Fig. 6.—Twin Fuse Holder and Mains Connection. (*A. F. Bulgin & Co. Ltd.*)

Where to Insert the Fuses

Suitable fuse positions in a typical receiver are indicated in the diagram reproduced at Fig. 4. The fuses inserted at F1 would protect the house installation from a heavy fault inside the set, or the set from further damage should the fault not clear itself. A fuse of from 1 to 3 amperes is quite light enough for this position. Although this fuse does much to protect the transformer, it offers little protection to the rectifier should a short occur in the receiver. A fuse at F2, rated for twice or three times the output of the rectifier valve, will give protection against accidental overloads, including breakdown of the reservoir condensers or of the smoothing choke. The rating of a fuse in this position must take into consideration the charging currents of the reservoir condensers. Fuses at F3, however, offer protection only against overload in the anode circuits of the receiving valves.

Fuse incorporated in the Wall Plug

Another portion of an all-mains radio equipment which is a source of risk, and should therefore be the subject of protection, is the much-neglected flexible which connects the set to the wall socket. This lead, from its very nature and position, is subject to hard wear and the risk of mechanical injury, and any fuses inside the set give it no protection. The only fuse which controls the flex, therefore, is that feeding the wall socket on the mains, and this, as has already been pointed out, is far too large in most instances to afford proper protection. Adequate safeguard can be ob-

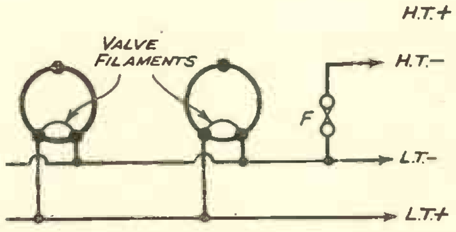


Fig. 7A.—THE CORRECT POSITION TO PLACE A FUSE TO PROTECT VALVE FILAMENTS.

tained, however, by use of a fuse incorporated in the wall plug top. Such a fused plug-top, by the M.K. Electric Ltd., is illustrated in Fig. 5. Neat double-pole fuses of the indicating cartridge pattern are concealed in the plug, and may be of 1, 2 or 5 amps. capacity to choice. If the smaller value is selected, it is unnecessary to fit input fuses to the receiver.

A Useful Inlet Unit

A useful inlet unit for the receiver is made by A. F. Bulgin, and is illustrated in Fig. 6. This fitment is in three parts: a holder containing two 1-amp. fuses, which is fitted to the set; a detachable section which fits on to the fuse holder and has two projecting pins; and a socket portion with insulated receptacles, to form the terminal of the flexible cord. It will be seen from the illustration that it is impossible to gain access to the fuses until the socket, with the mains connection, has been entirely withdrawn, so that the whole of the apparatus is "dead."

Fuses for Battery-operated Sets

Similar precautions by way of fuses

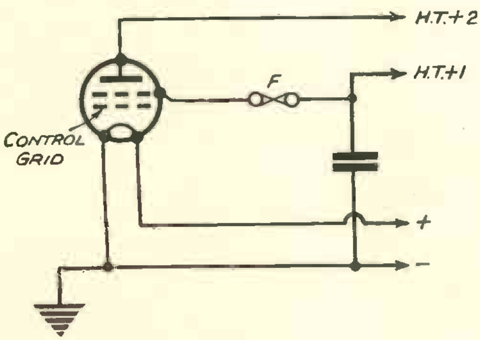


Fig. 8.—POSITION FOR FUSE IN SCREEN LEAD OF HIGH-FREQUENCY VALVE.

should also be applied to all battery-operated sets where high tension is obtained from an eliminator. In addition, all battery sets, whether fitted with an eliminator or used in conjunction with a high tension battery, should have a fuse inserted to protect the valve filaments from risk of being burned out as the result of high tension being applied to them. Such an accident is far from uncommon, and can occur by connecting the high tension leads to the low tension terminals in error, or by accidental contact between the high tension positive and the low tension circuit.

Where to place the Fuse to protect Valve Filaments

The correct position for this fuse is in the lead connecting the high tension

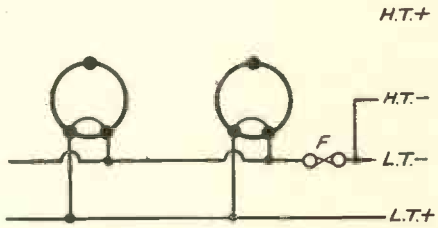


Fig. 7B.—THIS SHOWS THE INCORRECT POSITION TO PLACE A FUSE TO PROTECT VALVE FILAMENTS.

negative to the low tension negative or earth bus bar, as shown in Fig. 7a. The fuse should never be included in the main filament circuit as at Fig. 7b. If located here, it gives only half protection, and at the same time, if the fuse be of the popular "flash lamp bulb" type, its resistance will probably be sufficient to prevent the valve filaments from obtaining their full voltage.

"Screw Fuses."

A commonly-used type of fuse for battery sets is a small bulb of the flash lamp type, mounted in a screw holder, of which several types are on the market. The bulbs are obtainable in a variety of ratings, while the Belling-Lee "screw-fuses," which fit the same holders, are available in five sizes between 60 and 750 milliamps. Fuses of the glass tubular type are also very suitable for use in battery sets. In many receivers, terminals for the various battery leads are not fitted, and it is then convenient to include the fuses in the runs of the battery leads. A "flex fuseholder" consisting of a glass cartridge fuse enclosed in a tube of insulating material with attachments for the flexible cord is made by Belling and Lee, and a similar type by Bulgin.

Combined Wander Plug and Fuse

Several firms supply a combined wander plug and fuse for use at the negative high tension plug, and this form of fuse is another solution of the problem presented by the set having no terminals.

Protecting a Screened Grid Valve

In order to give further protection, a fuse may be fitted in the screen connection to a screened grid high frequency amplifying valve, to guard against the possibility of damage in the event of a short between the screening grid and control grid. The connections are shown in Fig. 8, and the rating of the fuse should be about 60 milliamps. The position of this fuse in the circuit should be carefully noted. It is so located that the charging current of the screen decoupling condenser does not pass through the fuse, and will therefore not cause it to blow unnecessarily.

Microfuses

Microfuses, consisting of a sheet of gold about one-millionth of an inch thick, stuck on to a sheet of celluloid, are extremely useful in wireless receivers. In the cartridge-type fuse the strips are fitted into glass tubes and gripped therein between two pairs of brass jaws, the protruding ends of which are covered by metal caps through which electrical connection is made. The great feature of the microfuse is the speed with which it blows. The time overload curve (Fig. 9) shows the speed of operation of a 150 m.a. microfuse under various conditions of overload as found from oscillograph tests. With an 8-fold overload, *i.e.*, an overload corresponding to short circuit conditions, the fuse blows in 1/1,000 of a second. Fig. 10 shows the relative speeds of fusing of the filament of a Mullard P.M.4 valve and a microfuse. These fuses are manufactured by Microfuses Ltd., 36, Clerkenwell Rd., E.C. 1.

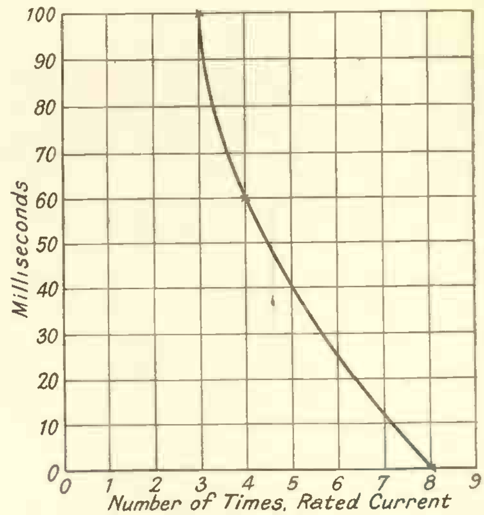


Fig. 9.—Graph showing Blowing Speed of a Microfuse. (*Microfuses Ltd.*)

It will be seen that, with an overload current eight times above normal, which corresponds to short circuiting conditions, the fuse blows in 1/1,000 of a second.

ISOLATING AND INSULATING DEVICES

There are many points in a receiver at which it is very easy to make an unwanted contact which will mean damage, and

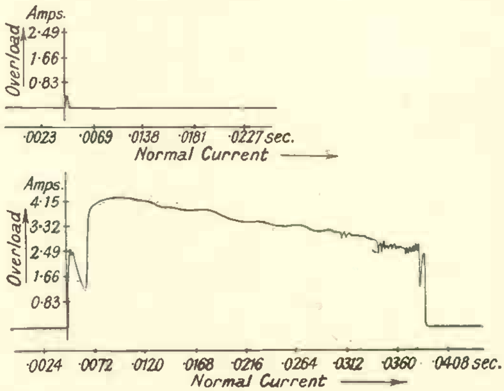


Fig. 10.—Relative Speeds of Fusing of a Valve Filament and a Microfuse.

These speeds are measured by an oscillograph, and it will be seen that the microfuse blows almost instantaneously with no appreciable increase in current, while the valve filament does not fuse until after an appreciable increase in current. Thus the use of a microfuse protects the valve from possible damage.

perhaps ruin to some part of the apparatus. Often a little care in providing extra insulation will obviate this risk. One such danger spot is the anode connection to a screened grid valve, and another is the connection to the side terminal of a pentode. The normal form of connection is an insulated terminal nut and flexible wire. Should the nut work loose, or the wire be disconnected by accident, or while making adjustments (although circuit adjustments should never be made while the high tension supply is connected), it is quite likely that the bared end of the flex may fall on to some other part of the apparatus, or on to the chassis, thereby earthing a portion of the high tension supply and possibly burning out one or more valves.


Fig. 11.—A SAFETY ANODE CONNECTOR. (*Belling Lee.*)

Safety Anode Connectors

This danger can be entirely removed by discarding the terminal nut and fitting to the end of the flex one of the Belling Lee safety anode connectors. This consists of a metal sleeve or socket which is to be screwed on to the threaded stem of the anode or auxiliary grid terminal of the valve, and a completely shrouded plug which is fitted to the end of the flexible lead and then plugged into the socket. Even should the lead be dropped carelessly inside the set, no short circuit can possibly occur. The use of this device is illustrated in Fig. 11.

Danger of Connecting Batteries to the Wrong Terminals

Another possible source of damage is the connection of batteries to the wrong terminals. Mention has already been made of the dire results of connecting the high tension supply to the low tension circuit; trouble may also occur if positive supply is connected to negative terminal, or *vice versâ*, or by the wrong connection of grid bias plugs. The use of clearly titled terminals, cable ends and leads greatly reduces these risks. The Belling and Lee indicating terminals with lettered, captive heads are almost too well known to require mention, but it should be noted that this and other firms supply in addition, plugs, sockets, wander plugs and other connection accessories, all lettered with such titles as "H.T.1," "H.T.2," "L.S.," and so forth. The list includes insulated and shrouded plugs and sockets which also prevent accidental short circuits.

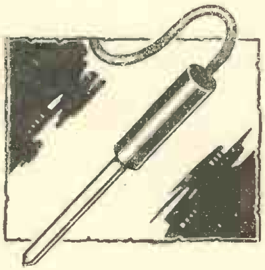


Fig. 12.—INSULATED TESTING PROD. (*J. J. Eastick.*)

Non-reversible Plugs and Sockets

In order to ensure correct polarity in all connections, non-reversible plugs and sockets may be employed. Many types are on the market, for mains and battery connection. One of the most ingenious, also due to Belling Lee, is a pair of lead-plated eye sockets for permanent attachment to the terminals of low tension accumulators, and having holes of different sizes into which two plugs, also of different size are fitted. With these accumulator connectors it is impossible, either deliberately or accidentally, to make incorrect connections.

Insulated Testing Prods

Many an unfortunate incident has occurred within a set while tests have been in progress, due to the test leads coming in contact with an unwanted portion of the wiring. Insulated testing prods similar to those illustrated in Fig. 12, avoid this risk. The prods consist of pointed brass rods which telescope into long insulating handles. As the prods are pushed down on the spot at which contact is desired, the points emerge slightly and make connection, but are insulated from all other parts of the set.

How to prevent the Danger of a Reaction Condenser breaking down

It is sometimes advisable to connect a fixed capacity condenser in series with a variable reaction condenser, to avoid what amounts practically to a short circuit of the high tension supply in the event of a breakdown in the insulation of the reaction condenser, which may happen owing to the accumulation of dust, or by mechanical damage to the vanes. A mica condenser of a value comparable with that of the reaction condenser is called for here. The total capacity of the arrangement will naturally be reduced.

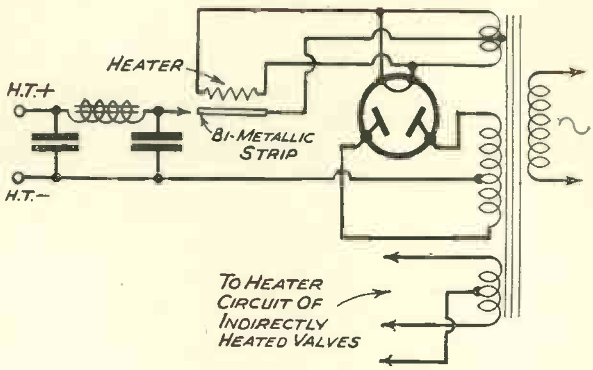


Fig. 13.—Control of High-Tension Switching by a Delay-Action Switch, when using Full-wave Rectifier Valve.

Isolating Condensers in D.C. Mains Set

A further example of the need for isolating condensers is the direct current mains set. These sets should be so designed that the aerial is coupled to the receiver through a condenser—usually of ·0001 mfd. or smaller, and the earth connection is also isolated from the mains by a condenser of high insulation. These points are fully dealt with elsewhere in this work, and are only mentioned here for the sake of completeness.

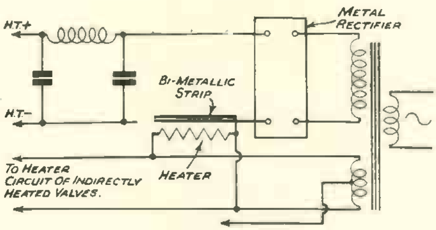


Fig. 14.—Control of High-Tension Switching by a Delay Action Switch, when Using a Metal Rectifier.

MISCELLANEOUS PROTECTIVE DEVICES

In an A.C. all-mains receiver employing indirectly heated valves there is a delay of about thirty seconds before the cathodes of the valves heat up sufficiently to give full emission. If the high tension supply is given by means of a directly heated rectifier valve or a metal rectifier, and the high tension is connected to the anodes of the indirectly heated valves before they are giving full emission, the rectifier is practically open circuited, and a high tension occurs which may cause damage.

Using a Delay Action Switch

Complete protection is given by the use of a delay action switch in the high tension lead. The Bulgin thermal delay switch, which is made in various types, operates on the principle of the bi-metallic strip. A strip comprising two different metals secured together is heated by the current passing through a winding, and, as it is heated, bends, owing to the different expansions of the two metals. When sufficiently bent, it overcomes the force of a spring, clicks over, and makes a contact closing a second circuit.

How the Switch should be connected

Figs. 13, 14 and 15 show the connections as applied to an A.C. set with rectifier valve, an A.C. set with metal rectifier, and a direct current mains set using indirectly heated receiving valves with the heaters of the valves operated in series.

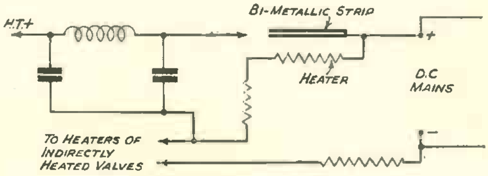


Fig. 15.—Control of High-Tension Switching by Delay-Action Switch, in a D.C. Mains Set.

THE STENODE

By J. ROBINSON, D.Sc., Ph.D., M.I.E.E.

A VERY interesting method for making scientific progress is to investigate the behaviour of a particular device under a variety of circumstances. Variations occur as the conditions change, and it is always useful to vary the conditions in the widest possible manner. An example of this is given by the electrical resistance of metals at various temperatures, the general case being for the resistance to rise and fall as the temperature rises or falls. As it would be highly desirable to have a material whose resistance is exceedingly low, tests were made at the lowest possible temperature, and the resistance was found to go near the vanishing point.

The Stenode is another application of the method for carrying the investigation of physical properties to the limit, and in this case the selectivity of wireless devices was pushed as far as possible. Selectivity is the property of a circuit which enables it to receive one frequency better than others, and as the selectivity is increased we are enabled to receive a narrow band of frequencies with very little effect from all others.

When Highly Selective Circuits have not been Used

Before the Stenode was introduced it was possible to obtain highly selective circuits, but they were not employed for the reception of wireless signals such as broadcasting, because they were considered unsuitable for this purpose. Actually, it was generally believed that if selectivity were made very high the portion of the signal which conveys the intelligence would not be received. It was believed that when we use such a circuit we would receive, in place of the variable waves, which are sent out from a transmitter, only continuous waves, and that the variable portion, which conveys the intelligence, would not be received. Put into technical language, a transmitter of telephony sends out waves whose frequency is constant, and whose amplitude is also constant when sending no intelligence. The waves are made useful for conveying intelligence by making the amplitude vary, or by modulating the waves. Fig. 1*a* shows continuous waves and Fig. 1*b* the modulated waves.

Opinion was general that if a very highly selective circuit was employed we should obtain the same result whether we received continuous or modulated waves, and thus it was thought to be useless to employ such highly selective circuits for receiving broadcasting.

The Sideband Theory

This difficulty will perhaps be understood more clearly by reference to the theory of telephony, which has become universally accepted. This theory is called the Sideband Theory, and is to the effect that any series, of modulated waves as in Fig. 1*b*, can be represented as the sum of a number of continuous waves of the same nature, as those of Fig. 1*a*, but with different frequencies and with different amplitudes.

—and what it is

Thus, if we transmit one musical note of frequency 500 c.p.s., which is a note about an octave higher than middle "C" on the piano, and if the frequency of the wireless transmitter is 1,000,000 c/s., the sideband theory states that this is the same as if we transmitted three series

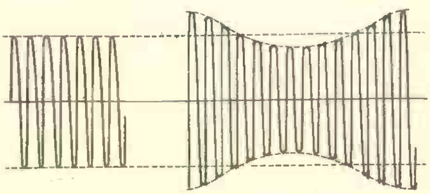


Fig. 1.—Continuous Waves and Modulated Waves.

of continuous waves simultaneously, of frequencies, 999,500 c/s., 1,000,000 c/s., and 1,000,500 c/s., the centre frequency corresponding to carrier waves and the two outside frequencies to the sidebands. When we transmit a passage of music, notes are employed from about 30 c/s. to 5,000 c/s., or even to 10,000 c/s., and thus, if we assume that 5,000 c/s. is the highest note, we have many continuous waves transmitted, ranging from 995,000 c/s. to 1,005,000 c/s.

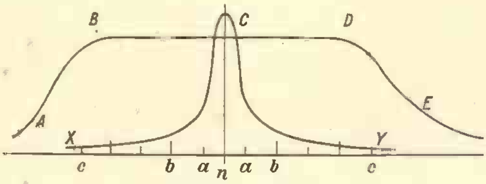


Fig. 2.—Diagram representing a Telephone Transmission.

Why Circuits of very High Selectivity were Considered Useless

As modulated waves can thus be considered as a series of continuous waves of different frequency, and in this case extending over a frequency range of 10,000 c/s., it appeared useless to employ very high selectivity, for this would imply that we would only receive frequencies, say, from 1,000,000 to 1,000,100 c/s. if we had a circuit so selective that it gave appreciable response only to waves whose frequencies are not more than 50 c/s. away. It thus became a recognised point of view that if we employed a circuit so selective as this it would receive only the carrier waves, and would cut off the sidebands. As the latter are essential to the correct reception of the signals, we thus see what a stumbling block there was in the path when anyone wanted to increase the selectivity for telephony purposes.

A telephone transmission could thus be represented, as in Fig. 2, with carrier waves of frequency "n," and with two sets of sidebands symmetrically placed with regard to the carrier. In order to receive this transmission, we should therefore have a receiver which will receive the sidebands "c" and "c_1" equally as well as the carrier. Thus, as these extreme sidebands are 10,000 c/s apart, we must have the resonance curve of our receiver something like A, B, C, D, E, of Fig. 2.

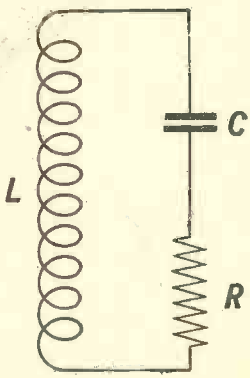


Fig. 3. — A Typical Tuned Circuit consisting of an Inductance and a Condenser connected in Parallel.

How the Stenode Works

The Stenode, however, employs a resonance curve something like X, C, Y, and we must now consider more closely how it was possible to arrange for correct reception with such a highly selective circuit, particularly where theory pointed to the fact that such a circuit would give us nothing but the carrier waves, which are unintelligible.

Some of the Properties of a Highly Selective Circuit

The reception of modulated waves by a circuit of very high selectivity will be better understood after we have examined some of the properties of a selective circuit. A typical tuned circuit consists of an inductance and a condenser connected in parallel. There are three controlling factors in such a circuit, the inductance, L, the capacity, C, and the resistance, R. The frequency depends principally on the values of L and C, whilst the resistance, R, controls other features.

Damping Depends on Amount of Resistance

If the resistance, R, were zero, the tuned circuit would continue to oscillate for ever once it had been excited in any way. The energy would alternate between the inductance and the condenser at regular intervals, there being nothing to stop it. However, it is not easy to obtain the condition where the resistance is zero, and when resistance is present the electrical energy is dissipated in the form of heat and in other ways, thus producing a gradual diminution of energy resulting in the vibrations being damped, so that each is lower than the

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SERVICING COLUMBIA RECEIVERS

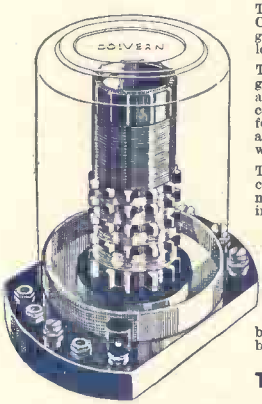
WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

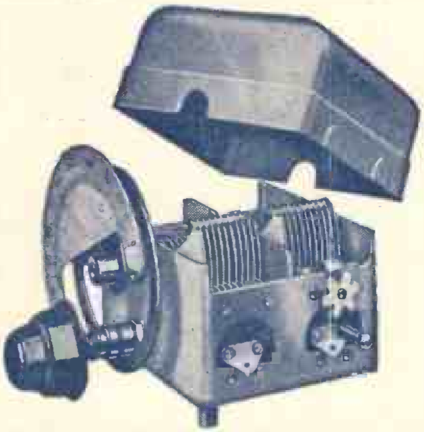
HIGH-FREQUENCY CHOKES

1/-

Part 16

IN ABOUT 24 WEEKLY PARTS





See Back Page.

PART 16.

preceding. The damping thus depends on the amount of resistance.

In wireless the tuned circuit of Fig. 3 is excited by incoming waves of a frequency identical with that of the circuit, and again by waves whose frequency is very nearly the same. For waves of the same frequency, n, we again find the resistance, R, having a large influence, and if R is zero we would have the succeeding incoming vibrations adding energy to the circuit, and this process would go on indefinitely, thus ultimately giving us an exceedingly large amplitude of vibration. Here again we see the significance of the resistance, for it places a definite limit on the maximum amplitude, and we have the conditions that for a large value of resistance or damping we obtain a comparatively small response, and this occurs after a few incoming vibrations. For a low value of resistance or damping a longer time is required to reach the maximum amplitude, but ultimately a high value is reached. These results are summarised in Fig. 4.

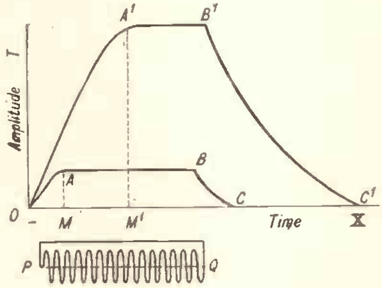


Fig. 4. — SUMMARY OF RESULTS SHOWING DAMPING EFFECT OF A RESISTANCE IN A TUNED CIRCUIT.

Time Required to Build up to a Maximum

Suppose waves of constant amplitude arrive for a definite time given by PQ, the actual amplitudes of vibration for two circuits at different intervals of time shown, the curve OABC giving the result for a high value of damping, and OA'B'C' for low damping. The maximum amplitudes MA and M'A' are inversely proportional to the resistance or damping. The time required to build up to the maximum increases as the damping falls, and again the time required to die down to zero also increases as the damping falls.

What Happens in a Highly Damped Circuit

With a highly damped circuit as in OABC, we thus have a condition in which the receiver rapidly comes to rest after it has once been excited, thus becoming ready for the next signal. In other words, such a receiver follows the variations of incoming signals fairly faithfully. The low damped circuit OA'B'C', however, requires a long time to build up and to die down, and it thus does not follow the incoming signals faithfully. When a series of telegraphic signals arrive, the highly damped receiver rises to its maximum and goes back to zero for each signal, as shown in Fig. 5. For incoming signals *a*, *b*, *c*, *d*, the highly damped receiver responds as at OAB, CDE, FGI, etc., each signal being distinct.

However, the low-damped circuit never comes to rest under these conditions, and the amplitude follows the curve OA'B'D'E'G'K'L'M'. It thus appeared as if we must be restricted to highly damped circuits in order to follow incoming signals, and thus that we could not obtain the benefits of high selectivity.

Amplitude Rises and Falls with the Incoming Signals

A closer examination shows, however, that the selective receiver follows the incoming signals after some sort of fashion, and that, although it is vibrating all the time, its amplitude increases whenever a signal arrives, as at B'D', or E'G', or K'L', and that its amplitude falls when the incoming signal ceases, as at A'B', or D'E', etc. Thus, although the receiver is never at rest, its amplitude rises and falls with the incoming signals. Thus the signals are represented, and the Stenode makes use of them.

Actually there is a large amplitude of oscillation in this receiver, and a comparatively small percentage change for each signal, but the actual rise and fall is about equivalent to the whole rise and fall for the highly damped circuit. In other words, the vertical fall from G' to K' is approximately the same as that from G to I, and thus the actual signal strength is about the same. We can thus employ circuits of high selectivity to receive signals and, in fact, it is immaterial whether these are of the telephonic or telegraphic type. This receiver has usually a large amplitude of oscillation, and its amplitude rises and falls with the incoming signals.

Effect of Modulation Frequency

This is, however, not by any means the whole story, and we find that the amount of rise and fall of the amplitude of the receiver depends on the modulation frequency. This can be seen from a telegraphic example, where we consider the effect of high and low speed signalling. In Fig. 6 the low- and high-speed incoming signals are shown. The response in a highly selective receiver which has already built up to its maximum amplitude is shown as ABCDEFG for the low-speed signals *abc*, and as A′B′C′D′E′F′G′ for the high-speed signals *defgh*.

The actual signals received in the two cases are given by the changes of amplitude, and for the low-speed signals the receiver has a comparatively long time to die down, thus giving the signals BC, which are stronger than the high-speed signals.

Signal Strength Inversely Proportional to the Modulation Frequency

There is thus a very important effect that the strength of signal diminishes as the signalling speed or as the modulation frequency increases. This has been accurately calculated, and for very highly selective circuits it is found that the signal strength is inversely proportional to the modulation frequency. The formula for this effect is comprehensive and shows how the signal strength depends on the selectivity of the circuit, which is defined by the damping factor, and, further, how it depends on the frequency of the carrier waves and on the modulation frequency. It is actually shown how the percentage modulation of the incoming signals (m) is diminished to a value m', when the damping factor is δ and when the carrier frequency is n and the modulation frequency is p. The formula is

$$m' = m \cdot \frac{n}{p} \cdot \frac{\delta}{2\pi}.$$

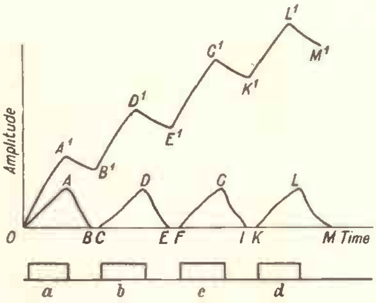


Fig. 5.—Showing How the Highly Damped Receiver Rises to its Maximum and goes back to Zero for each Signal.

Reinstating the Modulation Correctly

Having shown how all modulation frequencies are accepted by a circuit, no matter how high its selectivity may be, but that these modulations are not present in their correct proportions, it is necessary to provide some means for reinstating the modulation correctly. The signal strength being inversely proportional to the modulation frequency, it is necessary to introduce some device which will allow the higher modulations to pass more easily than the lower modulations, and a convenient way of doing this is to design a low-frequency amplifier which amplifies high frequencies more than low frequencies. In fact, for very high selectivity we must amplify strictly proportionally to the frequency.

Thus, finally, we have a receiver which consists essentially of a highly selective circuit, with a detector, followed by a low-frequency amplifier which amplifies high notes more than low.

Tuning Forks and Quartz Crystals

Some interesting features are introduced in carrying out these ideas in practice, and up to date the best results have been obtained by using the superheterodyne principle. Amongst the most selective devices known are tuning forks and piezo electric quartz crystals. With a tuning fork it is possible to obtain a resonance curve so sharp that when we are one or two cycles p.s. out of tune the response is only a few per cent. of that for resonance. However, measured in actual cycles distant from resonance, we find that, as the frequency of the fork or the crystal increases, the apparent selectivity diminishes.

Thus for a quartz crystal of a frequency of 50,000 c/s. the response, when we are 100 c/s. out of tune, is only a few per cent. of that at resonance. A crystal of frequency 50,000 c/s. or 100,000 c/s. is quite practical for broadcasting purposes, and obviously it has exceedingly large selectivity. However, for broadcasting purposes we have a large number of transmitters with frequencies varying from about 160,000 c/s. to about 1,500,000 c/s., and, unfortunately, the frequency of each crystal is fixed.

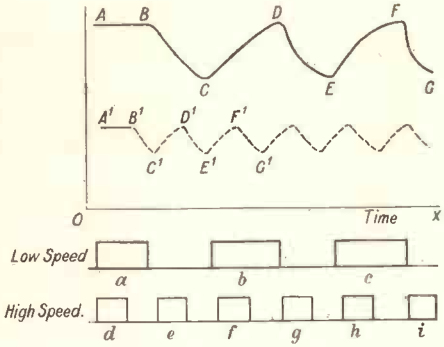


Fig. 6.—Showing the Low- and High-Speed Incoming Signals.

Where to Place the Quartz Crystal

Thus, practically, we find it best to employ the superheterodyne principle, placing the quartz crystal in the intermediate stage and then, after the second detector, to use a corrected amplifier.

Other ways of obtaining the High Selectivity

Instead of a quartz crystal the high selectivity in the intermediate stage can be obtained in other ways, but it is not easy to approach the quartz selectivity by ordinary wireless methods. However, by a series of tuned circuits, it is possible to obtain a resonance curve such that when we are 5,000 c/s. away from resonance the response is less than one per cent. of that at resonance. Stenodes made on this principle give excellent results.

The Autotone

The superheterodyne principle lends itself to this purpose of high selectivity, because we are concerned only with one frequency, the intermediate frequency. If we depart from the superheterodyne principle, we have the problem of maintaining the selectivity high when the frequency is changed. This introduces problems which naturally are capable of solution, and, in fact, receivers like the Autotone have already been described in which the selectivity is obtained by means of reaction.

Results Obtained with the Stenode

The practical results obtained by the Stenode have excited great interest, and they have brought forward much theoretical discussion. For broadcasting purposes, neighbouring channels are received with scarcely a trace of interference, even when the conditions are very severe, such as the reception of a weak distant station when geographically near to a neighbouring transmitter. Stations have frequencies allocated to them in such a manner that, as far as possible, they are never closer together than 9,000 c/s. However, there are so many stations that many of them are closer together than this. Practical Stenodes have so far been designed to give uniform reproduction for all tones up to 5,000 c/s., and even when transmitters are only 5,000 c/s. apart there is scarcely a trace of interference between them. One example of this in the broadcasting range is that of the two transmissions from the Eiffel Tower and from Warsaw, whose frequencies are 5,000 c/s. apart.

Because of these remarkable results, many highly theoretical treatises have appeared recently which have given special attention to the types of interference which occur between neighbouring stations, and showing how the Stenode completely eliminates some of them. Actually a Government committee was set up to investigate the problem, and the results of their investigations have recently been published as Radio Research Report No. 12, under the title "A Theoretical and Experimental Investigation of High Selectivity Tone Corrected Circuits." To enter into this question would, however, require much more space than has been allotted to me.

There remains here only one further remark, which is: that the advantages of high selectivity are not restricted to broadcasting, and there are many other applications, such as the multiplication of the words per minute that can be sent telegraphically over wires.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XII—MODULATION

THIS is our next step leading to detection of wireless signals. Before we can realise the nature of work done by the valves in our receiver, we must know the nature of electrical energy at the output end.

What is it we do in Broadcasting? We start with sounds in the studio. We interpret each sound as an electrical impulse or an electrical current of a certain form. As the nature of sound varies we obtain a series of currents which are amplified (strengthened) and brought to the aerial, which radiates electromagnetic waves. We intercept these electromagnetic waves with the help of our receiving aerial and obtain in the tuning circuit of the receiver currents of identical form to those flowing in the transmitting tuning system. Once more we amplify the currents so obtained, and, by means which will become clear later, sort them out and reduce them to such a form that they are able to energise the windings of our reproducing apparatus, such as telephones or a loud speaker, and cause the latter to produce a sound identical to those produced at the studio.

It is clear that if the sounds so obtained at the receiving end are to be the same sounds as those emitted at the studio, there must be a strict relation between each step taken so that no distortion creeps in.

State of Air around a Vibrating Body

Now, sounds are caused by waves in air. A body vibrating with certain speed will cause such waves. The energy possessed by the vibrating body is communicated to the molecules of air. This means that a solid body thus vibrating while swinging outwards will press on the surrounding molecules of air and will compress them. This compression will not be a sudden compression but a gradual one, as the body is gradually swinging outwards. In other words, the compression of air molecules will start from nothing, gradually increase to a maximum, and then as the body is swinging backwards the compression will gradually diminish till it becomes zero once more. Now, the body, having acquired inertia in its swing, will continue swinging to the other side of its neutral position, causing a rarefaction of air molecules behind it and a compression in front of it. This rarefaction will gradually grow to a maximum and then, as the body begins to swing back, gradually diminish to zero.

The state of air around a vibrating body will become clear from inspection of the nine stages shown in Fig. 1.

Air Waves—

It is clear, therefore, that both the swinging motion of a vibrating body and the compression and rarefaction of air, which we call *air waves*, are periodic events, going through a complete cycle of changes in the same way in which an alternating current goes through a cycle of changes, so that an air wave can be represented graphically in the same way as we represent a current or a voltage alternating from zero to a maximum, then to zero again, changing its direction and varying once more from zero to maximum and back to zero. This is shown in Fig. 2.

—and what they are

We shall remember, therefore, that an air wave is a periodic series of changes undergoing variations similar to those of alternating current or voltage. Just as in the case of any other periodic wave an air wave will have its amplitude (maximum swing of the vibrating body and therefore maximum compression of air or maximum rarefaction), its wavelength and its frequency.

Speed at which Air Waves Travel

Air waves, just as other waves, can be reflected, refracted and stopped. All sound or air waves travel with a definite speed, which is 1,100 feet (335 metres) per second at a temperature of 40° Fahrenheit. This speed varies with temperature.

Any vibrating body, be it a tuning-fork, the vocal chords of a human throat, strings of instruments or a column of air vibrating within a wind instrument, will produce waves in air, waves which, beating upon the ear-drum in our ears, will cause the latter to vibrate and give the brain an impression of some sound or other.

Here we have a transmitter in the vibrating body, the medium in air and the receiver in the human ear. The human ear cannot hear every kind of sound. The highest frequency of sound that a human ear can appreciate is the hum of a mosquito.

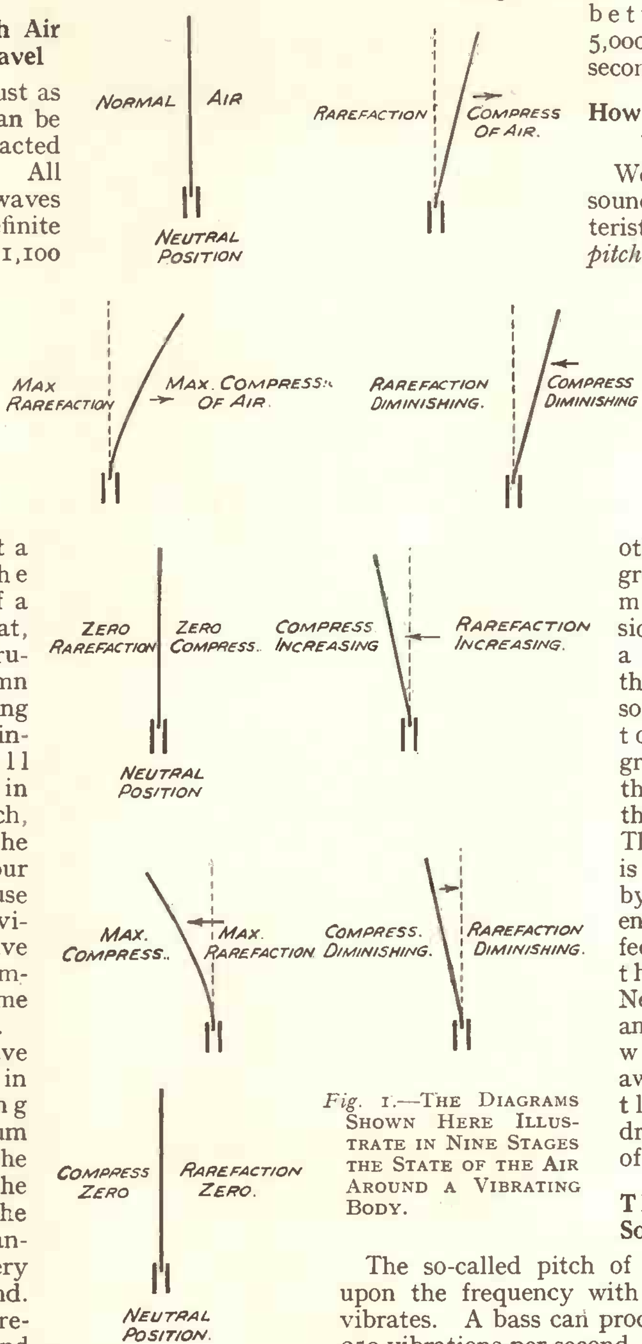


Fig. 1.—THE DIAGRAMS SHOWN HERE ILLUSTRATE IN NINE STAGES THE STATE OF THE AIR AROUND A VIBRATING BODY.

Audible Frequencies

The average audible frequencies lie between 30 and 5,000 vibrations per second.

How Sound is distinguished

We distinguish in sound three characteristics: *loudness*, *pitch* and *quality*. The loudness of sound depends upon the amplitude of the vibrating body, *i.e.*, the amplitude of the sound wave. In other words, the greater the maximum compression of air around a vibrating body the louder the sound will appear to us as the greater will be the pressure upon the ear-drum. The loudest noise is that produced by an aeroplane engine running 10 feet away from the listener. Next to it comes an express train when 12 feet away, and then the pneumatic drill at a distance of 20 feet.

The Pitch of Sound

The so-called pitch of sound depends upon the frequency with which a body vibrates. A bass can produce from 80 to 350 vibrations per second, a baritone from 96 to 384, a tenor from 128 to 480, a soprano from 240 to 1,150. A violin will deal with frequencies from 190 to 3,100, and a piccolo from 500 to 4,600 cycles per second.

Two notes an octave apart mean that the frequency of the higher note is double that of the lower note.

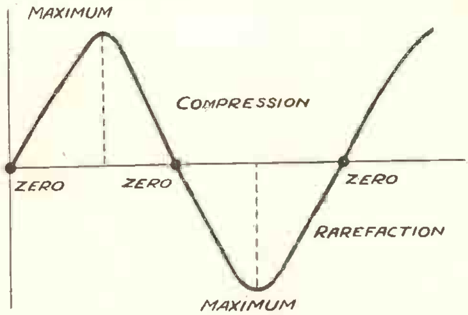


Fig. 2.—Showing how an Air Wave can be Represented Graphically.

The Quality of Sounds

The quality of sounds depends upon the *form of the wave.* In Fig. 2 we have a regular wave showing regular and gradual changes in rarefaction and compression of air. There are waves, however, which are far from being so regular. The changes may be very sudden. In order to be able to appreciate what such a wave form means let us consider Fig. 3. Top, left, we have a wave which represents the changes in air compression and rarefaction when the letter O is pronounced. Top, right, we have the same produced by a violin. In the bottom figure a clarionet is at work. It is thanks to these differing wave forms that we are able to distinguish one instrument from another, *i.e.,* to distinguish the quality of sound.

Fig. 3.—Three Different Wave Forms.

Top, left, wave representing changes in air compression and rarefaction when the letter O is pronounced; top, right, wave produced by a violin; bottom, wave produced by a clarionet.

To sum up: if a body is vibrating mechanically it will produce air waves possessing a great deal of energy, and these air waves on reaching a light body at rest will cause the latter to vibrate with the same frequency with which the waves are produced. A thin diaphragm can thus be made to vibrate by means of sound waves.

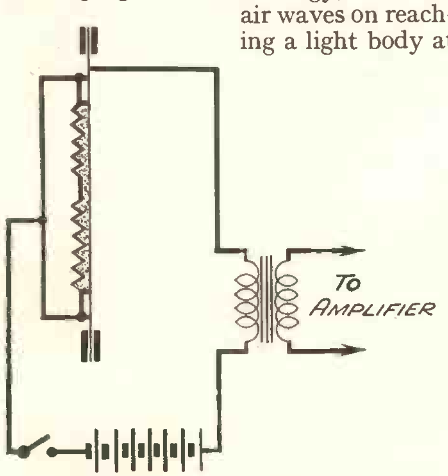


Fig. 4.—The Carbon Microphone.

How Sound Waves are Converted into Electrical Energy

Now, let us see how we can convert the energy of sound waves into electrical energy, or, in other words, variations in the sound waves into corresponding varying electrical currents.

In order to vary an electrical current in a circuit we must vary, when the E.M.F. is constant, either the resistance of the circuit, its inductance or its capacity. All these three methods are adopted in broadcasting.

The Microphone

For the purpose of varying the resistance of a circuit by means of sound waves there is a piece of apparatus called the carbon *microphone* (Fig. 4). This consists of a solid carbon grooved disc, the grooves being arranged spirally. In front of the carbon disc is clamped a carbon diaphragm the outer edge of which rests upon a cotton-wool ring, which in turn rests upon the outer edge of the carbon block. The space between the diaphragm and the block, within the grooves, is filled with fine carbon granules.

How the Microphone Works

A circuit is formed, as shown in Fig. 4, consisting of the microphone, a key, a battery, and the primary winding of a transformer. When the key is pressed down the circuit is closed and a current of constant strength is flowing through the circuit. This current will remain constant while the carbon diaphragm is at rest. Should sound waves impinge upon the diaphragm and cause the latter to vibrate, the pressure upon the carbon granules within the microphone will start to vary. The carbon granules when they are closely packed by the diaphragm pressing upon them will offer less resistance to the passage of the electric current than when they are loosely packed, so that for every variation in the pressure of the diaphragm there will be a corresponding resistance offered by the carbon granules, and, therefore, there will be a corresponding strength of current. As the diaphragm vibrates, the current will change, so that every variation in the intensity of the sound wave will be interpreted by a corresponding electrical impulse in the circuit. As soon as the diaphragm stops vibrating the current becomes constant again.

How the Currents are passed on to the Aerial

These currents flowing through the microphonic circuit on going through the primary winding of the transformer will create a varying magnetic field around the primary, and this varying magnetic field will induce similar currents in the secondary, from whence the currents are brought to an amplifier, there strengthened and passed on to the aerial.

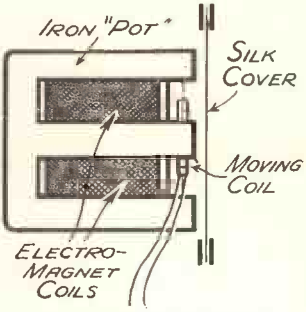


Fig. 5.—The Magnetophone.

Since sound waves are controlling the strength of current in the microphonic circuit, they will be indirectly controlling the strength of current in the aerial, and, therefore, they will be indirectly controlling the form of the electro-magnetic waves radiated by the transmitting aerial.

The Magnetophone

Another form of microphone, controlling the inductance of the microphone circuit, is shown in Fig. 5. It consists of a cylindrical iron "pot," in the centre of which is a solid core of an electromagnet. A coil is mounted on this core, and when a current is made to pass through the electromagnet coil a magnetic field will come into existence within the iron of the pot and the space between the edges (the air gap).

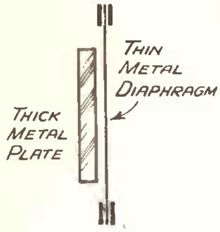


Fig. 6.—A Condenser Microphone.

Within the influence of this magnetic field is placed a small coil of fine wire which is delicately balanced and is free to swing under the slightest provocation. This coil is connected to the amplifying circuit. In front of the coil and the electromagnet is stretched a fine gauze cover. When sound waves are produced in front of such an arrangement, they cause the fine coil to vibrate in a magnetic field, and the coil in vibrating will cut a varying number of lines of force of the magnetic field, and thus will vary the current induced in it, or, in other words, will vary the inductance of the microphone circuit. (The inductance, it must be remembered, depends upon the number of linkages.) Once more for every intensity of sound wave we shall have a corresponding strength of electrical current.

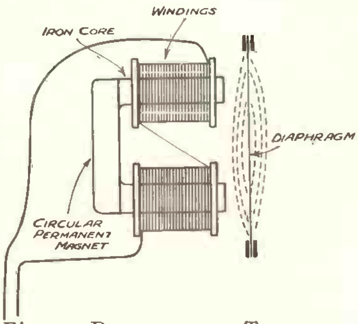


Fig. 7.—Details of a Telephone Receiver.

A Condenser-Microphone

The third form of the

microphone is shown in Fig. 6. This is a condenser-microphone. This is merely a form of a condenser and consists of a thick metal disc in front of which is mounted a tightly stretched thin metal diaphragm. Since the capacity of a condenser, amongst other things, depends upon the distance between the plates, as the thin diaphragm is vibrating under the influence of sound waves, the distance between the two plates will vary, and, therefore, the capacity of the microphone as a whole will vary. The varying capacity will result in a varying current in the circuit.

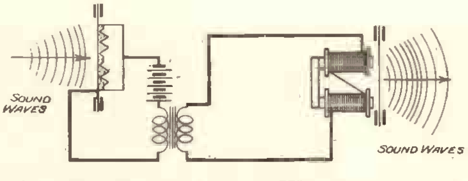


Fig. 8.—Showing the Windings of a Telephone Receiver Connected to a Microphone Circuit.

This is how we convert sound waves into electrical currents.

How Electrical Currents are reconverted into Sound Waves

Now let us see how we can reconvert electrical currents into sound waves. This is done with the help of a device called a *telephone receiver*, or a loud speaker. We shall study the latter in detail when dealing with reproduction of wireless signals, but in the meantime let us see what the telephone receiver will do for us in this direction. A telephone receiver consists of a permanent circular magnet to which are clamped two iron cylinders to serve as cores to the telephone windings (Fig. 7).

What happens in the Telephone Receiver

When a current is normally flowing through the telephone windings the cores become magnetised and attract the iron diaphragm clamped in front of them. The diaphragm is so mounted that it can be attracted by the poles of the electromagnet, but is unable to come into contact with them. If the windings of the telephones are connected to a microphone circuit, as shown in Fig. 8, what will happen is that sound waves produced in front of the microphone will produce in the microphone circuit varying currents which are controlled by these sound waves. If these currents are brought to the windings of the telephone receiver, *viâ* a transformer, they, in their variations, will vary the intensity of the magnetic field and cause it to change, so that the iron diaphragm, under the influence of this changing magnetic field, will start to vibrate and cause sound waves in air.

Since it is the sound waves produced in front of the microphone that make the microphone diaphragm vibrate and thus vary the resistance of the microphone circuit, and, therefore, the current in it, and since it is these varying currents that produce a varying magnetic field around the poles of the telephone electromagnet, it is clear that the telephone diaphragm will vibrate in the same way in which the microphone diaphragm has been vibrating and the same sound waves will be produced.

This being so, it is an easy matter to follow the next step, which is shown in Fig. 9. M is the microphone, A is the amplifier, Trs is the transmitter, R is the receiver, and Ls is the loud speaker, which is merely a form of a telephone receiver.

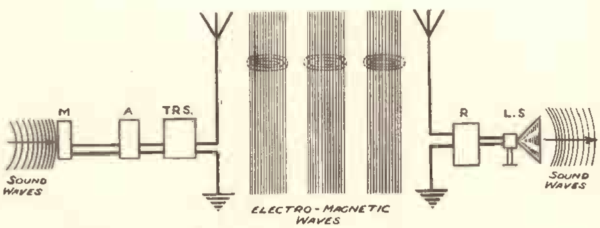


Fig. 9.—This Shows the Next Step

M is the microphone; A, the amplifier; Trs is the transmitter; R is the receiver, and LS is the loud speaker, which is merely a form of telephone receiver.

Carrier Waves

The microphone circuit is closed and a constant current is flowing through it; this current is passed on, *viâ* the amplifier, to the transmitting apparatus, and from thence to the aerial. Thus, before the microphone diaphragm comes into action, *i.e.*, before sound waves are emitted before the microphone, there is a regular current flowing in the whole of the transmitting system and the transmitting aerial is radiating a regular electromagnetic wave. This regular current, which is the foundation of our future variation and which will "carry" these variations is called the *carrier current*, and the wave caused by it is called the *carrier wave*. Such a carrier wave on reaching the receiving aerial will induce in it a regular current (provided the receiving aerial is tuned to the incoming wave), and this regular current, on passing through the receiver, will flow through the telephone windings and will deflect the telephone diaphragm, but will not make it vibrate and therefore will not cause any sound waves.

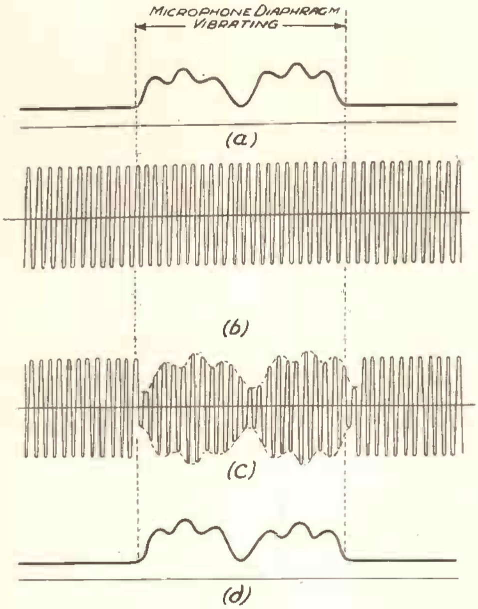


Fig. 10.—THIS SHOWS GRAPHICALLY HOW THE VARIOUS CHANGES OCCUR IN OUR TRANSMITTING AND RECEIVING SYSTEM.

Under certain conditions a carrier wave may cause the diaphragm to vibrate in a regular manner so that a steady musical, unvarying note is produced.

Modulated Waves

However, as soon as sound waves are emitted in front of the microphone, the current in the microphone circuit, and, therefore, through the amplifier, the transmitter and in the aerial will lose its regularity and will become a *modulated* current, *i.e.*, a current bearing the characteristics of the variations of sound waves. This will cause the emission of a modulated wave, a wave which is now being indirectly controlled by the sound waves in front of the microphone. This modulated wave will produce varying currents tuned to it in the receiving circuit, currents which on reaching the loud speaker windings will cause the loud speaker diaphragm to vibrate in the same way in which the microphone diaphragm was vibrating.

How Distortion is caused

Since we are dealing with electrical currents both in our transmitting and our receiving systems, we must take care that any variations that may occur in the nature of these currents are due solely to the variations in sound waves. Should some extraneous variations take place, our currents will change their character, and the resultant currents will be distorted as will the final sound waves.

Sound Waves are quite separate from Electromagnetic Waves

It is clear from the above that as far as sound waves are concerned they cannot do more than to make the microphone diaphragm vibrate and change the character of currents flowing in the transmitting system. Sound waves do not get mixed up with electromagnetic waves, as so many amateurs fondly imagine. The sound energy is transformed into electrical energy, the electrical energy is transformed into electromagnetic energy, and electromagnetic energy is transformed into electrical energy, which is finally transformed into sound energy.

Why a High-frequency Current is used for Carrier purposes

The carrier current which is made to flow in the transmitting system is a high-frequency current, the frequency of which depends upon the wavelength of transmission. The reason why a high-frequency current is used for carrier purposes is that as the frequency of transmission becomes lower the wavelength increases. Since the wavelength depends upon the product of inductance and capacity, transmission on large wavelengths, and, therefore, low frequencies, would mean the use in both the transmitting and the receiving circuits of large coils and condensers. This would mean prohibitive costs of installation on the part of the listener.

High frequencies are easily transformed into lower frequencies within the receiver, and thus transmission on high frequencies is much more economical than that on low frequencies.

How the various Changes occur in Transmitting and Receiving Systems

Now let us study Fig. 10, which shows graphically how the various changes occur in our transmitting and receiving systems. (*a*) Shows some arbitrary form of microphone current produced under the influence of a sound wave impinging upon the microphone diaphragm. You will notice that at first, before the microphone diaphragm starts vibrating, this current is steady, and begins to vary as soon as the microphone diaphragm begins to vibrate. (*b*) Shows the regular high-frequency carrier current flowing in the aerial before the microphone diaphragm comes into action. (*c*) Shows how the carrier current is changed when the microphone currents come into existence. You will notice that when the character of the carrier current is changed it is only its form that is affected, and not its frequency. This remains the same. In (*d*) we have the final form of current flowing through the loud speaker windings, after the receiver valves have dealt with the received modulated carrier currents. You will notice the identity of character of (*a*) and (*d*).

There are several methods of modulation, but since this is a purely transmitting problem it is at the moment outside the scope of this present article.

Distortion nearly always due to Receiver

I have mentioned distortion of original sound waves as being due to extraneous influences within the circuit. If such occurs the listener may be sure that the B.B.C. transmitting part of it is beyond reproach. There is very seldom anything wrong with the transmission, and therefore in the case of distortion one should look for the cause within the receiver. The usual cause of distortion is incorrect treatment of valves. But before we can appreciate the niceties of these problems it is necessary for us to study the question of valves, the manner of their action, their treatment and care. We shall do this in the next part of this work.

SERVICING

COLUMBIA RECEIVERS

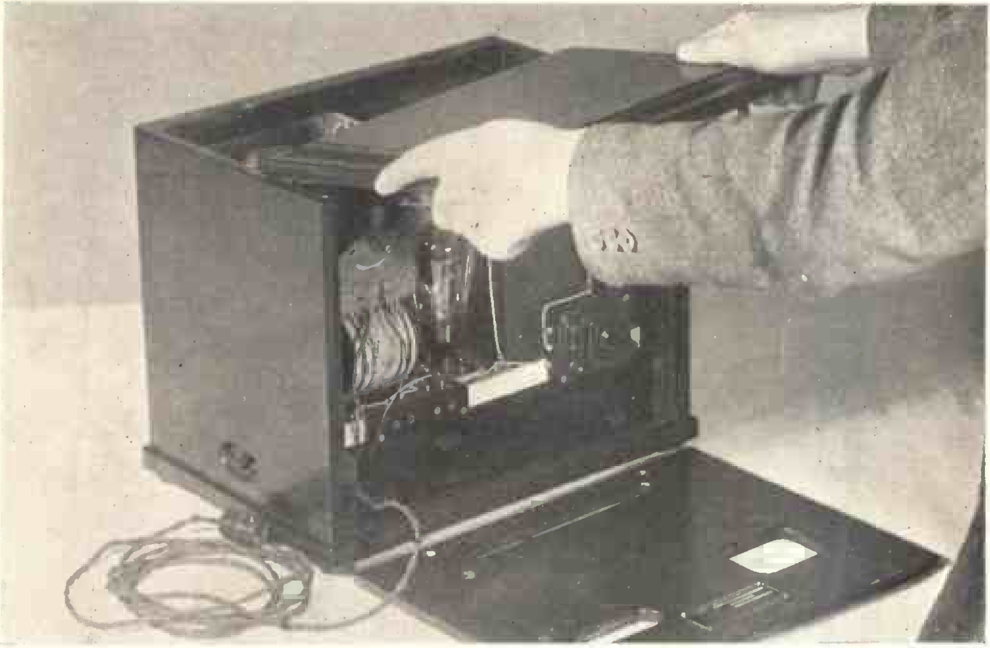


Fig. 1.—DISMANTLING THE COLUMBIA 307 RECEIVER.
This shows how the top slides back after the back has been removed.

MODEL 302 A.C.

THIS radiogramophone consists of a Model 304 receiver combined with a Model 250 electric gramophone, with provision for switching the output stage of the gramophone amplifier behind the receiver.

How to Remove Amplifier or Radio Chassis

To remove the amplifier or radio chassis from the cabinet, first remove the four bolts which hold the amplifier down to the lower deck, the nuts being underneath the cabinet. Release the coloured leads from the left-hand row of terminals, which are lettered, and carefully note down the colour of lead to its respective terminal. The leads on the right-hand side of the amplifier board can now be released, and as these are in sequence no difficulty should be experienced when replacing.

Remove the two plugs with armour-covered leads on the left-hand side of the amplifier ; the difference in length of lead will denote the correct socket. Also remove a similar plug on the right ; this is the mains connection. The amplifier can now be withdrawn.

Renewing Condenser Block

If it is necessary to renew the condenser block or mains transformer, the holding strip and bolts are conveniently situated, but care is necessary in rewiring

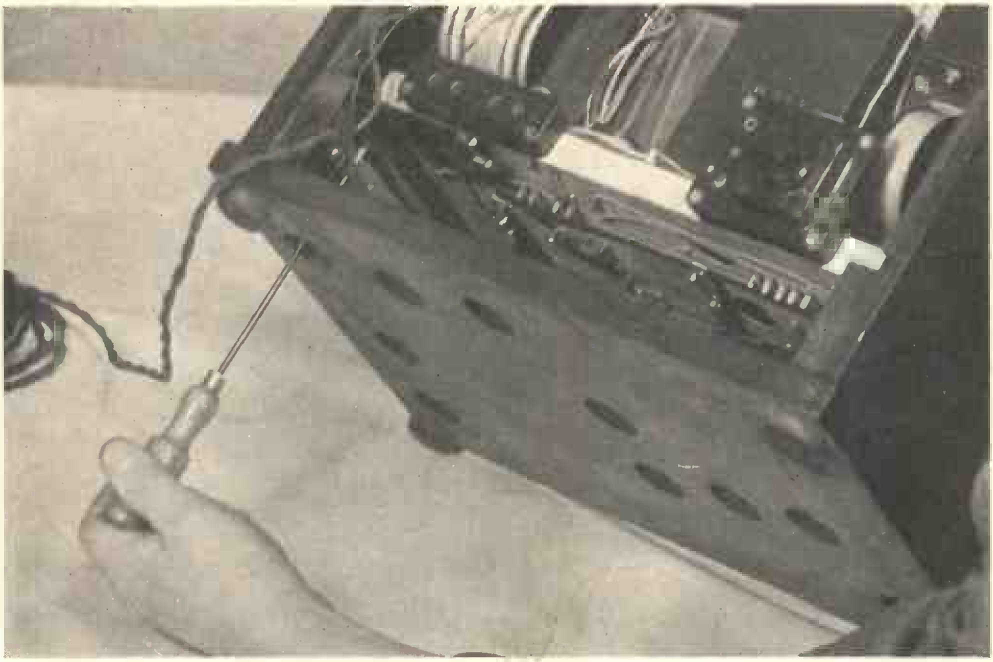


Fig. 2.—THIS SHOWS THE METHOD OF RELEASING THE CHASSIS SCREWS.

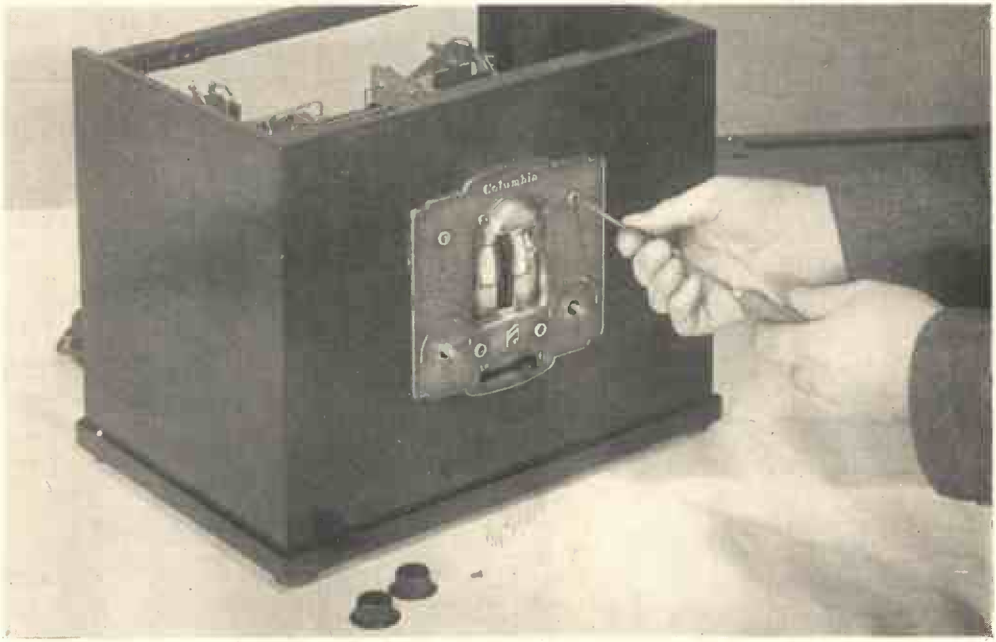


Fig. 3.—HERE WE SEE THE CONTROL KNOBS AND ESCUTCHEON BEING REMOVED.

owing to the numerous connections. Make a rough sketch and write down the connections.

To remove the radio chassis, unsolder the leads marked 1 to 10 on the strip at the back of the chassis, and also the intensifier and wave range switch knobs, together with the escutcheon. Take out the four bolts which hold the chassis to the ledge on which it rests, and after releasing the earth, aerial, and speaker (one) leads the chassis can be withdrawn. See Model 304 for service to chassis.

The speaker can be taken out by unfastening the bolts through the speaker deck; it is not fastened in front.

Fig. 4.—How the Mains Switch Lead is removed.

Operating Data

Emission of valves on amplifier board

Place switch to gram

- U65/550 or R.H.1. Rectifying valve . . . 45–50 m.a.
- U65/550 or R.H.1. Rectifying valve . . . 45–50 m.a.
- PP3/425 or B.12. Power valve . . . 20–30 m.a.
- PP3/425 or B.12. Power valve . 20–30 m.a.
- Mazda L210. Ampl. valve . . 2–4 m.a.

Voltages on amplifier board

- L.T. Across fil. of L210 . . 2 volts D.C.
  - Across fil. of each PP3/425 . 7·5 volts A.C.
  - Across fil. of each U65/550 . 7·5 volts A.C.
- H.T. Between plate and fil. socket of L210 . . 140 volts approx.
  - Between plate and fil. socket of PP3/425 . 390 volts approx.
- G.B. Between grid and fil. socket of L210 . 4·5 volts
  - Between grid and fil. socket of PP3/425 . 90 volts

Emission of valves in the receiver (right to left)

Place switch to radio high power

- 1st S.G. valve (place intensifier to max.) 1·5–3 m.a.
- 2nd S.G. valve . . . 1·5–3 m.a.
- 3rd S.G. . . . 1·5–3 m.a.
- Power ,, . . . 15–20 m.a.
- Detector ,, . . . 0·5–1 m.a.

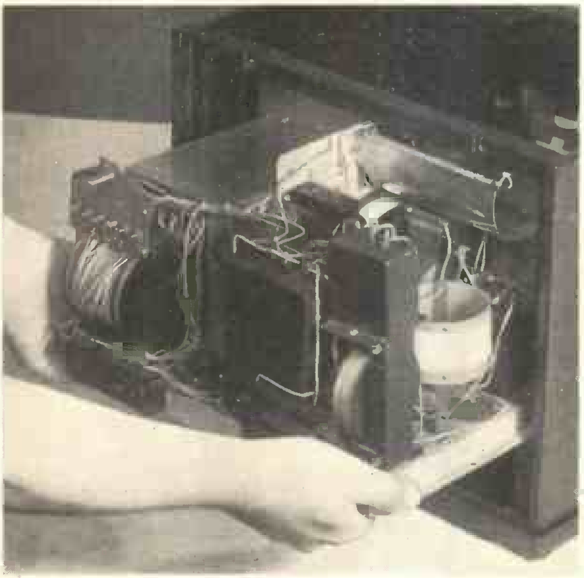


Fig. 5.—How to withdraw the Chassis of the Columbia 307 Receiver.

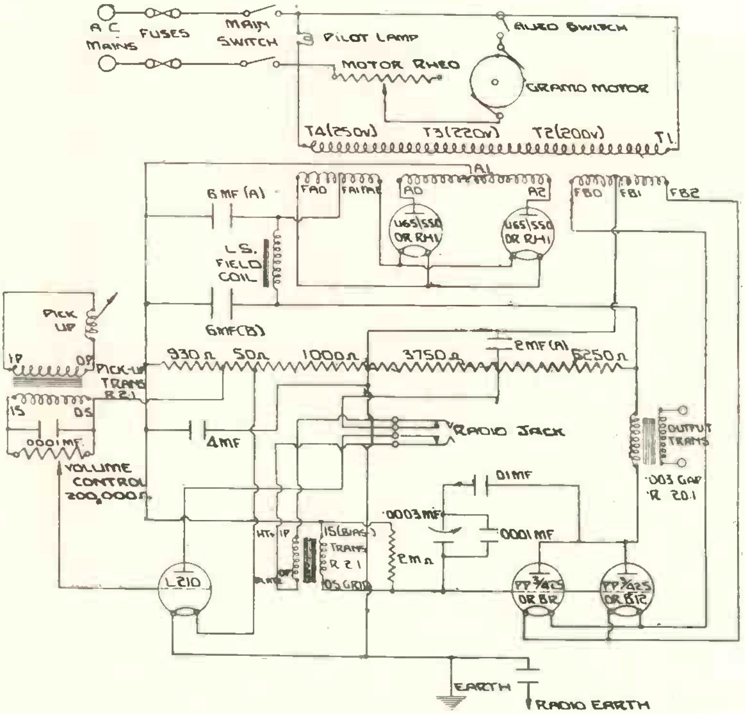


Fig. 6.—Theoretical Circuit Diagram of Columbia 250 A.C. Receiver.

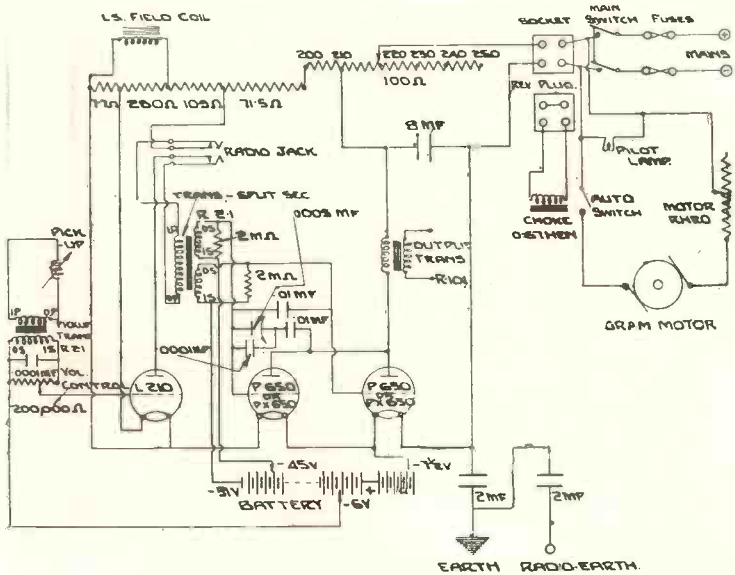


Fig. 7.—Theoretical Circuit Diagram of Columbia 250 D.C. Receiver.

Voltages of valves in the receiver

L.T. Between terminals 6 neg. and 7 pos. 2 volts

Between terminals 8 neg. and 9 pos. 2 volts

Place intensifier knob halfway between min. and max. when making the L.T. measurement, as the load on the metal rectifier is slightly different for different positions o the intensifier knob. An adjustable resistance behind the master change switch allows the voltage between terminals 6 and 7 to be adjusted to 2 volts.

Note.—The chassis is $1\frac{1}{2}$ volts negative to filament.

H.T. Between terminals
- 5 neg. and 4 pos. about 75 volts.
- 5 neg. and 3 pos. about 150 volts.
- 5 neg. and 2 pos. about 180 volts.
- 5 neg. and L.S. lead about 120 volts.

G.B. Between
- G.B. + and G.B.1 $1\frac{1}{2}$ volts.
- G.B. + and G.B.2 9 volts.
- G.B. + and G.B.3 12 volts.

MODEL 302 D.C.

This is the D.C. counterpart of the Model 302 A.C., the mains resistances being tubular zenite rods under the cover on the amplifier board.

Details which apply to the A.C. model also apply to this one, but care must be taken not to allow the receiver lid to touch the metal casing of the motor whilst the

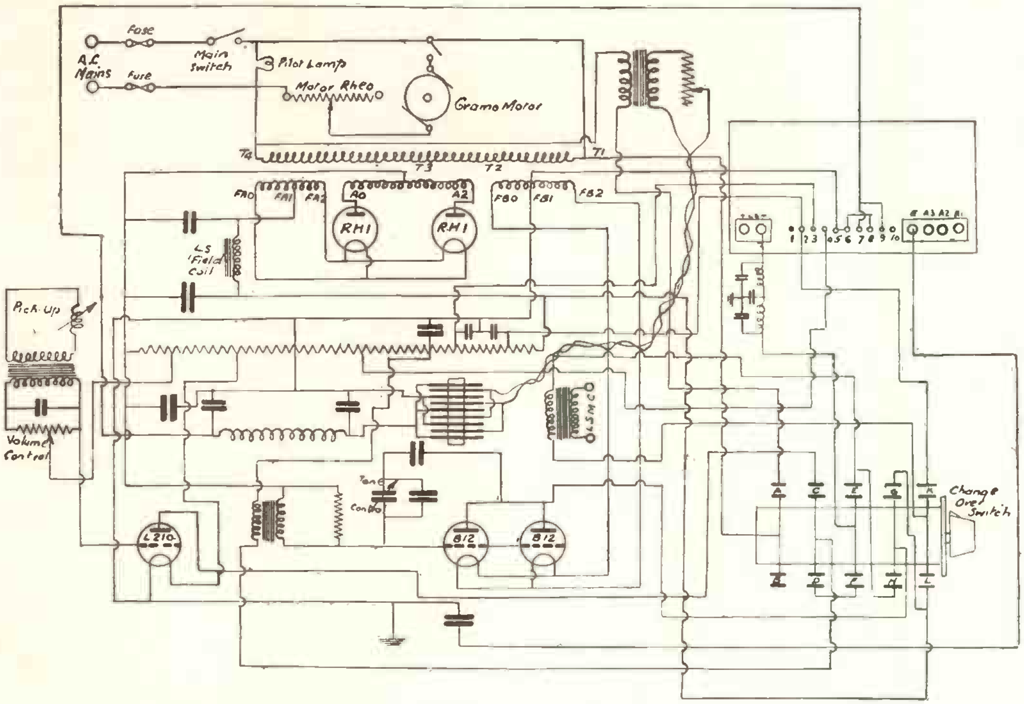


Fig. 8.—Theoretical Circuit Diagram of Columbia 302 A.C. Receiver.

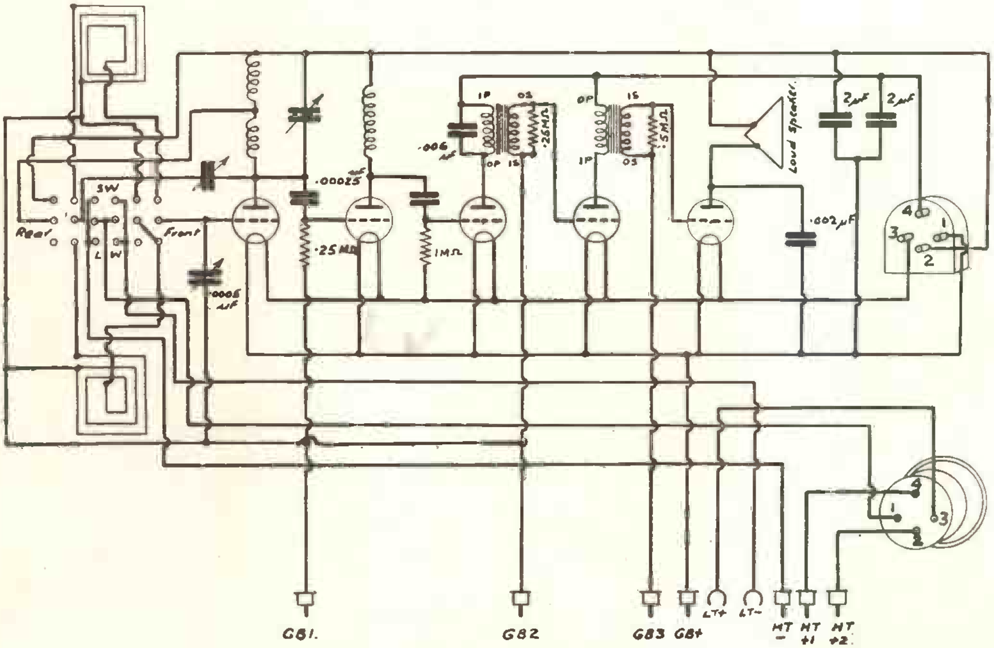


Fig. 9.—Theoretical Circuit Diagram of Columbia 303 Battery Receiver.

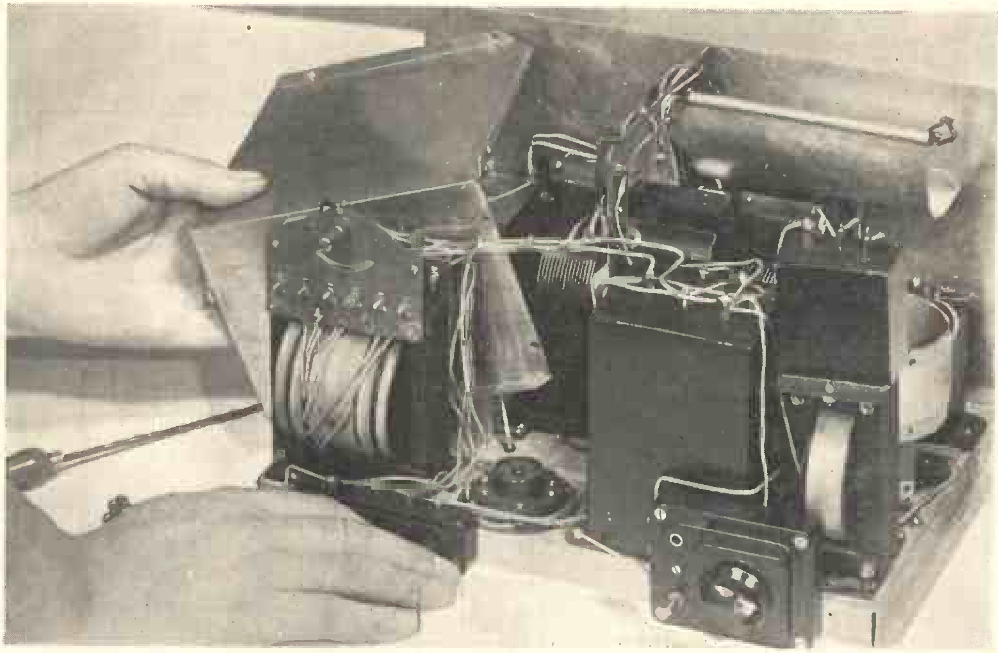


Fig. 10.—How to remove the Screening of the Columbia 307, 308 and 310 Receivers.

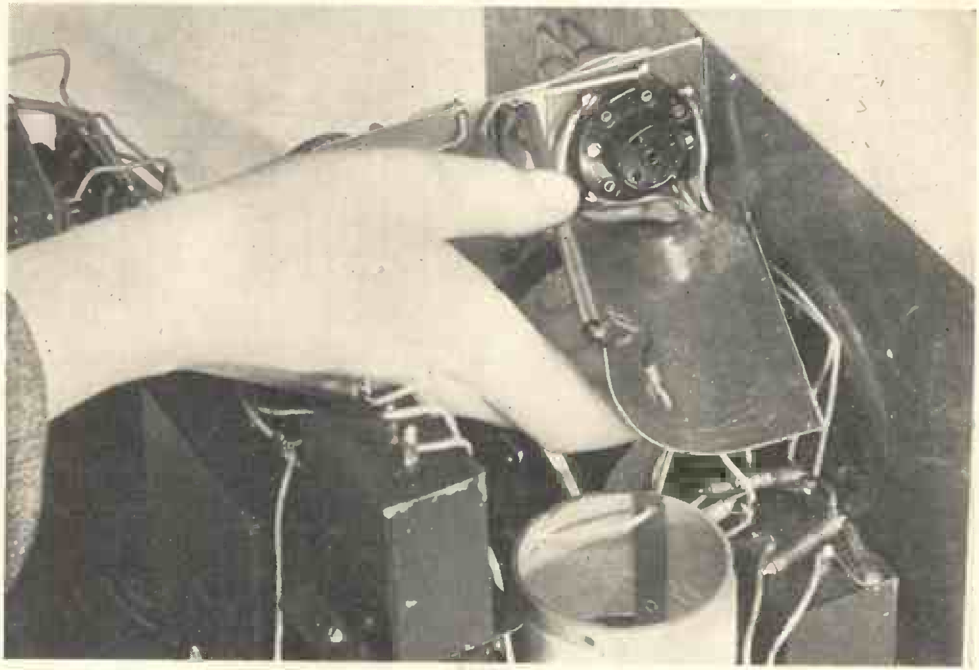


Fig. 11.—Removing the Screen Grid Shield of the Columbia 307, 308 and 310 Receivers.

Showing the anode lead through shield tube ; also bias de-coupling resistances and condenser block underneath.

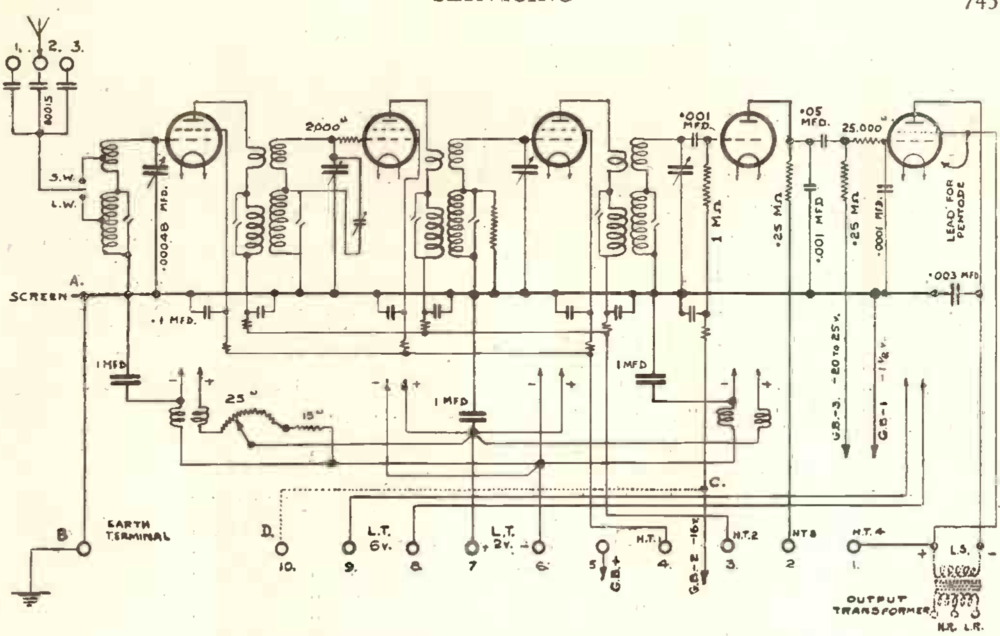


Fig. 12.—Theoretical Circuit Diagram of Columbia 304 Receiver.

set is alive or the two P650 filaments will blow.

In order not to rob grid bias from H.T., bias batteries are employed, and the inter-valve transformer in the gramophone amplifier has a split secondary, each winding being connected to its own bias and power valve, the anodes of which are joined. Should reception be intermittent and not due to usual causes, the L.T. resistance is probably fractured. This is the centre of the three zenite rods and has a resistance of 515 ohms. The receiver chassis is similar to Model 304 D.C.

Operating Data

Emission of valves on amplifier board
Place switch to gram
PX650. Power valve . 20–30 m.a.
,, ,, . 20–30 m.a.

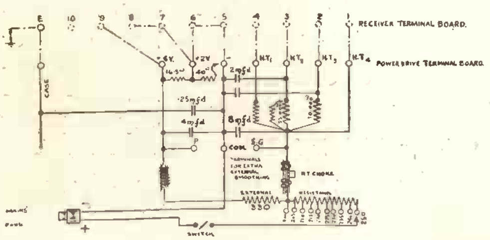


Fig. 13.—Theoretical Diagram of Power Drive for Columbia 304 D.C. Receiver.

Mazda L210. Amplifying valve . 2–4 m.a.
Voltages on amplifier board
L.T. Across fil. of L210 valve . 2 volts
Across each PX650 valve . 5·5–6 volts
H.T. Between plate and fil. sockets of L210 about . . 140 volts
Between plate and fil. sockets of each PX. 650 about 185 volts
G.B. As marked on the tags.

Emission of valves in the receiver (right to left)
Place switch to radio high power.
1st S.G. (place intensifier to max.) 1·5–3 m.a.
2nd S.G. . . . . . 1·5–3 m.a.
3rd S.G. . . . . . 1·5–3 m.a.

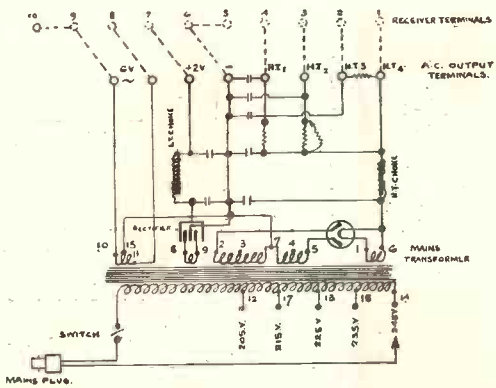


Fig. 14.—Theoretical Diagram of Power Drive for Columbia 304 A.C. Receiver.

Power		15–20 m.a.
Detector		0·5–1 m.a.

Beware of warning *re* chassis lid and motor casing

Voltages in the receiver

L.T. Between

6 neg. and 7 pos.		2 volts
8 ,, 9 ,,		6 volts

An adjustable resistance behind the master change switch allows the voltage between 6 and 7 to be adjusted to 2 volts.

H.T. Between terminals

5 neg. and 4 pos.	about	65 volts
5 ,, 3 ,,	,,	125 ,,
5 ,, 2 ,,	,,	180 ,,
5 ,, 1 ,,	,,	175 ,,

G.B. Between terminals

G.B. + and G.B.1	1½ ,,
G.B. + ,, G.B.2	16½ ,,
G.B. + ,, G.B.3	18 ,,

MODELS 303 A AND B

A straight five-valve portable having one stage of tuned anode H.F., one stage of choke capacity H.F., detector and two L.F. The reaction condenser is a neutralising condenser, therefore the receiver can be made to oscillate by moving the reaction knob to left or right of central position. An L.F. valve is used in first H.F. stage in order to obtain neutralisation. The short-wave frame in back has a tap to which the green grid lead can be connected if the minimum wavelength is not low enough. Speaker cone can be withdrawn without taking out grid bias supports. The anti-microphonic spring valve holders can be repaired without taking out the valve deck by soldering ½ inch of 6 B.A. rod at the pivoting point of the spring.

If it is necessary to take out the deck or tuning panel for repair, disconnect the speaker leads and the leads to the frames. Unscrew the grid bias battery supports from the base of the cabinet and the three screws holding the deck; then take off the switch and reaction knobs and unscrew the four screws holding the tuning panel. The panel and deck will lift out together.

Models C and D

A straight five-valve portable with two stages of choke capacity H.F., otherwise similar to 303 A and B. Some models have a cone shield which it is necessary to remove before the cone can be taken off and the deck is supported in a slightly different way.

Operating Data

Emission

	Right to left 303 C.D.	303 A.B.
1st H.F. valve	1–2 m.a.	1½–3 m.a.
2nd H.F. ,,	1–2 m.a.	1–2 m.a.
Detector ,,	0·25–1 m.a.	0·25–1 m.a.
L.F. ,,	1–3 m.a.	1–3 m.a.
Power ,,	3–6 m.a	3–6 m.a.

Voltages

L.T.		2 volts
H.T.	H.T.1	81 volts
	H.T.2	108 volts
G.B.	G.B.1	1½ volts
	G.B.2	3 volts
	G.B.3	7·5 or 9 volts

These models are also run from eliminator Model 305, giving approximately same values as tabulated above, but the grid bias battery is still operative.

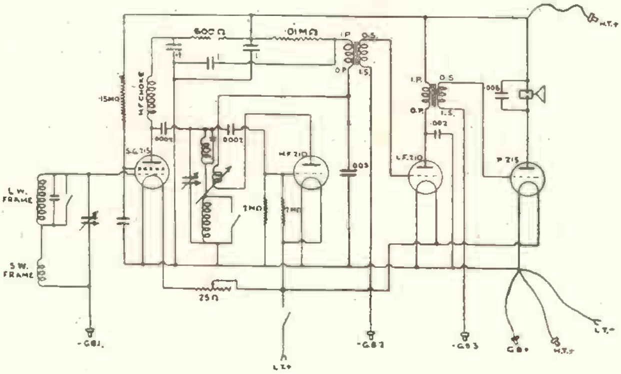


Fig. 15.—Theoretical Circuit Diagram of Columbia 306 Portable Receiver.

MODEL 304 A.C.

Three stages of S.G. H.F. amplification are employed with anode bend detector coupled by resistance-capacity to power valve, which is fed from 6 volts A.C. The other valves are of battery type fed by metal rectifier. Volume control is by resistance in filament of first H.F. valve, and if turned up too far, the detector overloads on very loud stations. Two tuning condensers on each section of dials, with friction clutch between dials and a trimmer to trim second tuned circuit to aerial circuit. This trimmer is behind the escutcheon. The filament volts across terminals 5 and 7 can be adjusted by the length of eureka wire in systoflex between the metal rectifier and transformer. Take great care not to make a dry joint at this connection.

Fig. 16.—Disconnecting the Aerial Condenser of the Columbia 307, 308 and 310 Receivers.

This is done prior to removing front of chassis.

How to take Receiver out of Chassis

To take the receiver out of the chassis, unsolder the leads coming up from the power unit, take off the intensifier and wave-range switch knobs and escutcheon then the four bolts which go up through the ledges on which the chassis rests and the chassis will withdraw. The power unit can now be removed. In order to test the chassis out of the cabinet, either place the chassis and power unit back to back and solder the leads to the chassis strip, remembering to cross them over, or place the chassis on two blocks

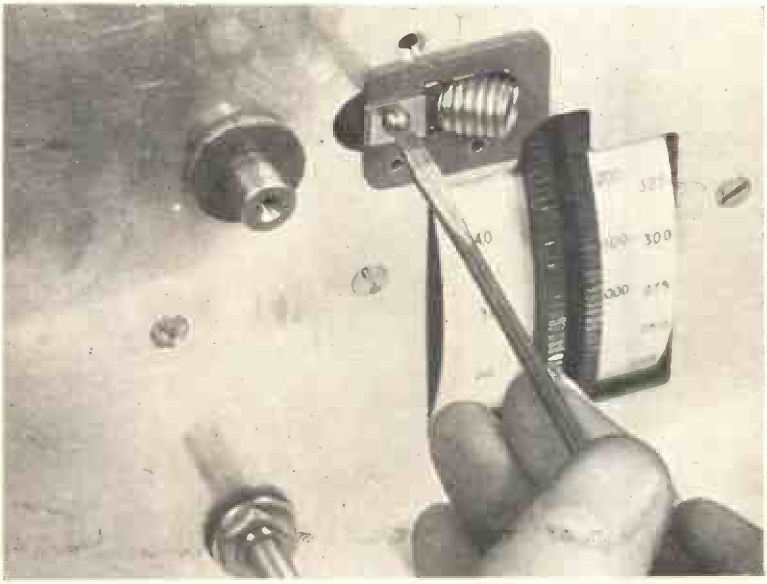


Fig. 17.—Releasing the Pilot Holder and Front Screws of the Columbia 307 and 310 Receivers.

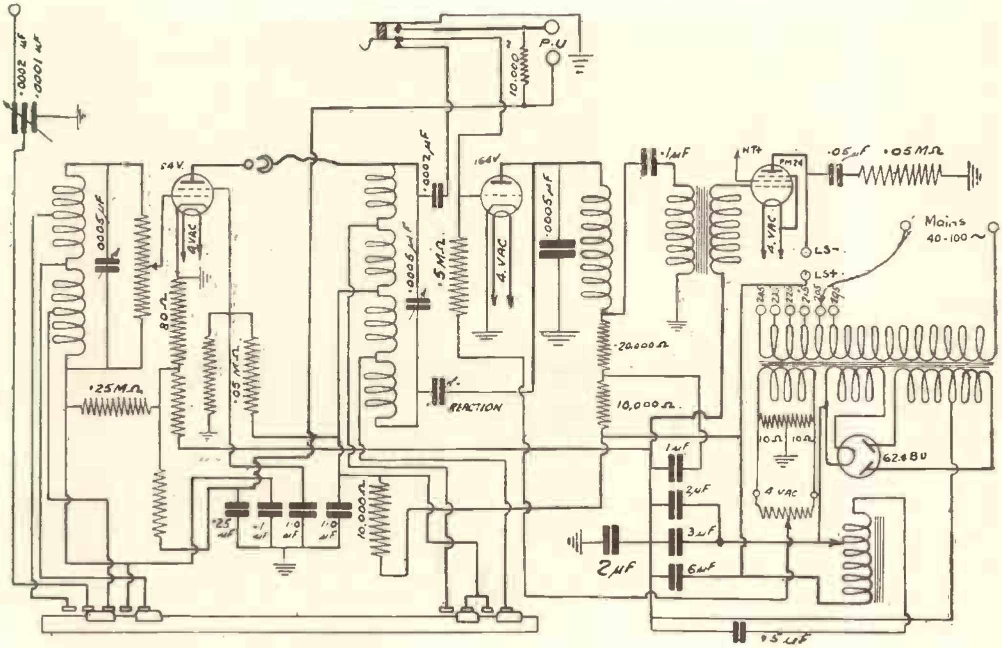


Fig. 18.—Theoretical Circuit Diagram of Columbia 307 A.C. Receiver.

above the power unit as if it were in the cabinet.

About a dozen small screws hold the top of the receiver on, and when this is removed the tuning compartments are accessible.

Operating Data

Emission, valves right to left

1st S.G. (place intensifier knob to max.)	1·5–3 m.a.
2nd S.G.	1·5–3 m.a.
3rd S.G.	1·5–3 m.a.

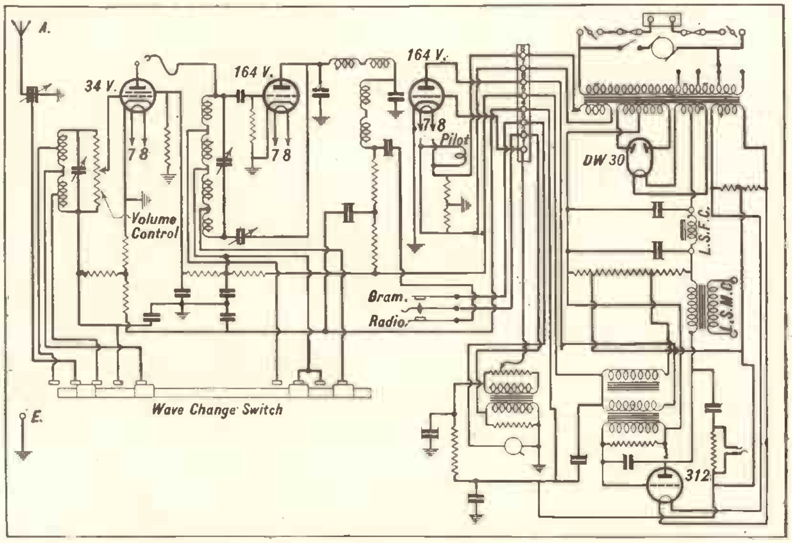


Fig. 19.—Theoretical Circuit Diagram of Columbia 308 Receiver.

Power	.	15–20 m.a.
Detector	.	0·5–1 m.a.

Voltages

L.T. Between

6 neg. and 7 pos.	.	2 volts
8 ,, 9 ,,	.	6 volts A.C.

Place intensifier half-way between min. and max. when measuring between 6 and 7.

H.T. Between

5 neg. and 4 pos.	about	60–70 volts
5 ,, 3 ,,	,,	110–120 ,,
5 ,, 2 ,,	,,	170 ,,
5 ,, 1 ,,	,,	180 ,,

G.B. Between

G.B. + and G.B.1	$1\frac{1}{2}$ volts
G.B. + ,, G.B.2	$16\frac{1}{2}$,,
G.B. + ,, G.B.3	18 ,,

MODEL 304 D.C.

This is similar to Model 304 A.C., and the mains resistance is external to the receiver, the red lead being the adjustable mains tap, the blue lead H.T., and grey L.T.

Particulars are as for the A.C. model, and there are 6 volts across the power valve.

Operating Data

Emission, valves right to left

1st S.G. (place intensifier to max.)	$1\frac{1}{2}$–3 m.a.
2nd S.G.	$1\frac{1}{2}$–3 m.a.
3rd S.G.	$1\frac{1}{2}$–3 m.a.
Power	15–20 m.a.
Detector	0·5–1 m.a.

Voltages

L.T. Between terminals

8 neg. and 9 pos.	6 volts
6 ,, 7 ,,	2 ,,

(Place intensifier knob half-way between max. and min. when measuring 6 and 7.)

H.T. Between terminals

5 neg. and 4 pos.	about	65 volts
5 ,, 3 ,,	,,	115 ,,
5 ,, 2 ,,	,,	170 ,,
5 ,, 1 ,,	,,	180 ,,

G.B. Between

G.B. + and G.B.1	$1\frac{1}{2}$,,
G.B. + ,, G.B.2	$16\frac{1}{2}$,,
G.B. + ,, G.B.3	18 ,,

MODEL 304 BATTERY

Similar to D.C. model arranged for batteries, but the power valve is 2 volts. All operating data similar to the D.C. model.

MODEL 304 I.D.H.

This is similar to other 304 models, but indirectly heated valves are used with the exception of the power valve, which is directly heated. The volume control varies self bias on the two first H.F. valves, the anode bend detector and power valve having a grid battery for bias.

Note.—G.B.1 is detector bias, and G.B.2 power bias.

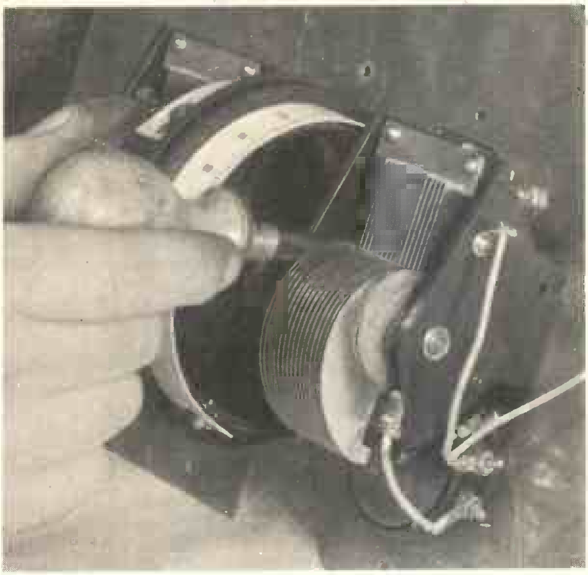


Fig. 20.—Method of Removing Condenser from Front Panel of Columbia 307, 308 and 310 Receivers.

Chassis and power unit can be taken out complete as per other 304 instructions, with this exception :—

There are two trimmers behind the escutcheon, one trims the medium waves of the first H.F. to the aerial circuit and the other trims the second H.F. to the third H.F.

Operating Data

Emission, valves right to left

1st S.G. } (Place intensifier	2–2·6 m.a.
2nd S.G. } to max.)	2–2·6 m.a.
3rd S.G.	2–2·6 m.a.
Power	24 m.a.
Detector	0·5–1 m.a.
L.T. All receiving valves	4 volts A.C.
Rectifying valve	4 ,,

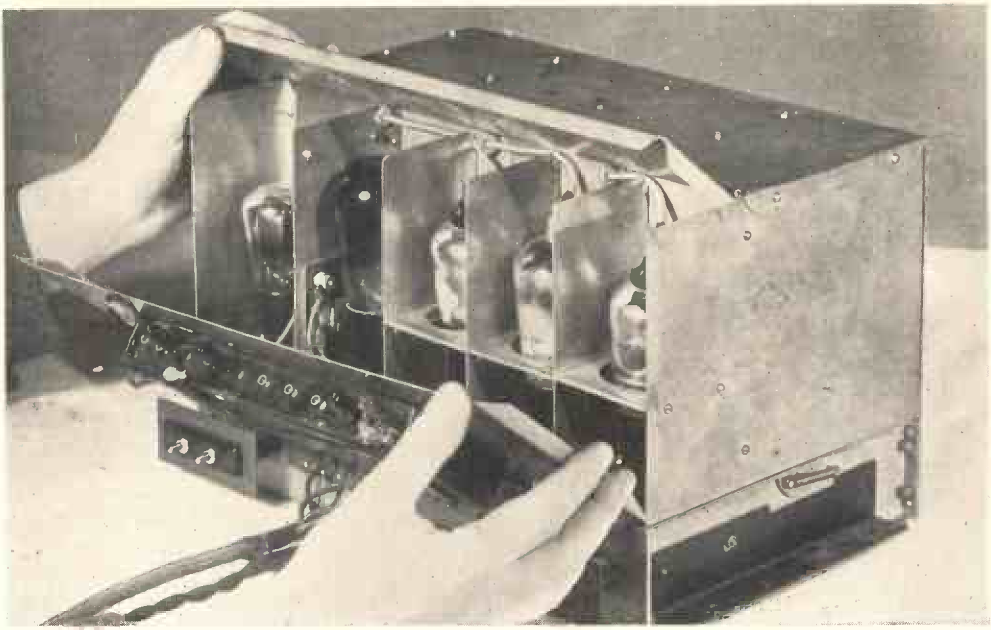


Fig. 21.—How the Valve Compartments on Columbia 302 and 304 Receivers are Exposed prior to removing Top.

H.T.	Between chassis and anodes of 1st, 2nd, 3rd S.G. anodes	120–140 volts
	Between chassis and screen of 1st, 2nd, 3rd S.G. valves	60–80 ,,
	Between chassis and anode of power valve	190–200 ,,
H.T.	Between chassis and anode of detector valve	160–180 volts
G.B.	Between	
	G.B. + and G.B.1	$22\frac{1}{2}$–24 ,,
	G.B. + ,, G.B.2	18 ,,

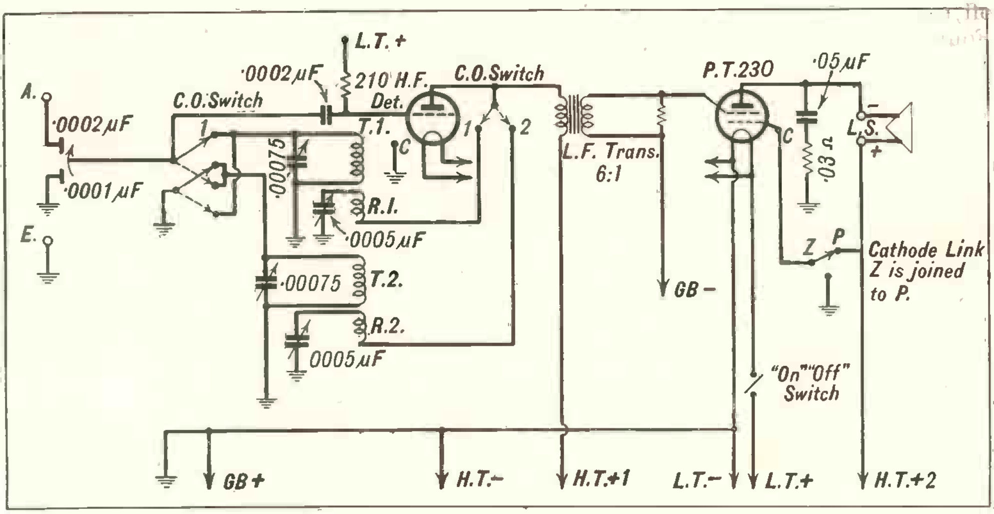


Fig. 22.—Theoretical Circuit Diagram of Columbia 309 Battery Receiver.

MODEL 305 A AND B

Power units similar to that fitted to Models 304 D.C. and 304 A.C., but with resistance values to make them suitable to run portable Models 303 from A.C. or D.C. mains respectively and have voltage measurements as tabulated for Models 303.

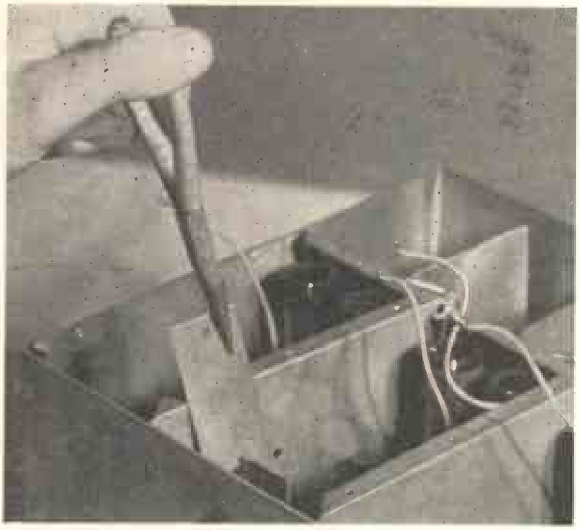


Fig. 23.—This shows the Top removed from the Columbia 302 and 304 Receivers.

Note the leads disconnected from tuning condensers. The spindle guard is being withdrawn.

MODEL 306

A four-valve suitcase portable. S. G. detector L.F. and power valve. Has two-gang condensers with rocking stator as trimmer, and although the trimmer knob has continuous movement, the end of trimmer adjustment is easily felt. The H.F. valve is choke capacity coupled to tuned grid.

To remove the chassis, take off the two escutcheons marked tuning and on-off switch, when the leatherette panel will lift off, exposing the screws holding the chassis. Four screws are in the bottom and one each side of the case. With these removed the chassis will lift out and can be serviced without disconnecting the frame windings and speaker which are in the lid. Take off the fret to service the frame windings or speaker.

Operating Data

Emission, valves left to right	
S.G. valve	1–2 m.a.
Detector valve	1–1·5 m.a.
L.F. valve	1–2 m.a.
Power valve	5–6 m.a.
Voltages	
L.T.	2 volts
H.T. Between	
H.T. – and H.T. +	120 ,,
H.T. – and screen	70–80 ,,
G.B. Between	
G.B. + and G.B.1	1½ ,,
G.B. + ,, G.B.2	3 ,,
G.B. + ,, G.B.3	7½ ,,

MODEL 307 A.C.

A three-valve table model receiver, S. G., detector and pentode output valve. The H.F. is tuned anode and the detector is resistance capacity coupled to the intervalve transformer. A hum bucking circuit is used for smoothing (see the H.T. choke), and a hum adjusting device consisting of grid leak of detector brought to potentiometer across heater winding.

To remove the chassis take off the front knobs and escutcheon plate ; unsolder the wire from transformer to mains lead and take out four bolts (two from above and two from below) which secure the chassis to the runners. The chassis will now draw out.

Should the switch contacts appear a trifle erratic due to film, a few rapid movements of the switch arm is sufficient to clear.

If it is necessary to service the tuned anode circuit or reaction condenser the shield must be taken off, but screws holding this are clearly visible. The filter unit is further shielded by the small shield.

Operating Data

Emission	
S.G. valve	0·3–1 m.a.
Detector valve (right, front)	
Radio	2–4 m.a.
Gram	2–4 m.a.
Pentode (right, back) about	20 m.a.
Voltages	
L.T. Across heater terminals	4 volts A.C.
Across rectifier filament terminals about	5·5 volts A.C.
H.T. S.G., chassis to anode	130–140 volts
S.G., chassis to screen	70–80 ,,

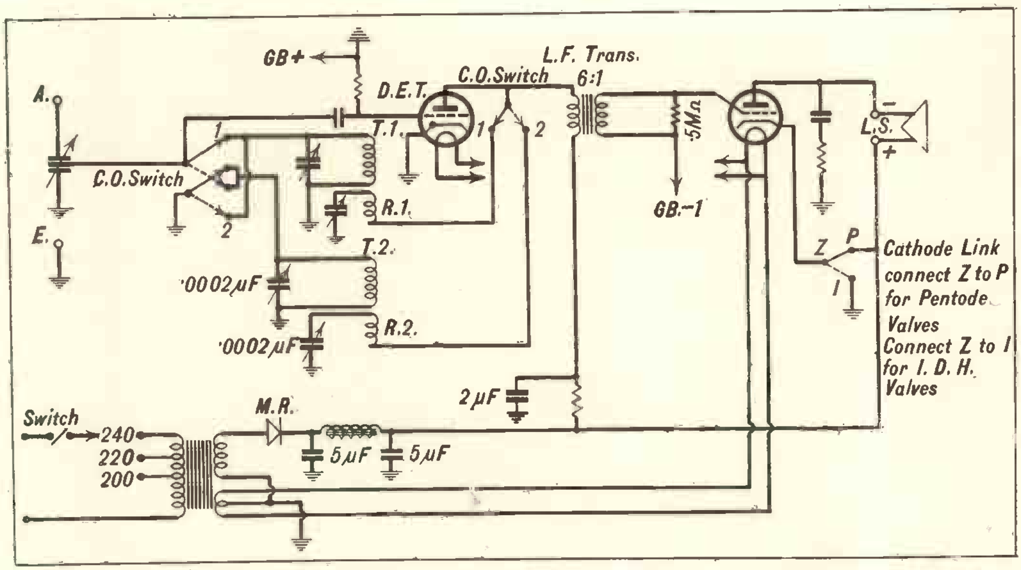


Fig. 24.—Theoretical Circuit Diagram of Columbia 309 A.C. Receiver.

Detector, chassis to anode. Radio . 40–50 volts
Gram . 50–60 ,,
Pentode, chassis to screen . . about 165 ,,

H.T. Pentode, chassis to anode . about 140 volts
G.B. S.G. . . . . 3 ,,
Pentode . . . 10 ,,
Detector on gram. . 3 ,,

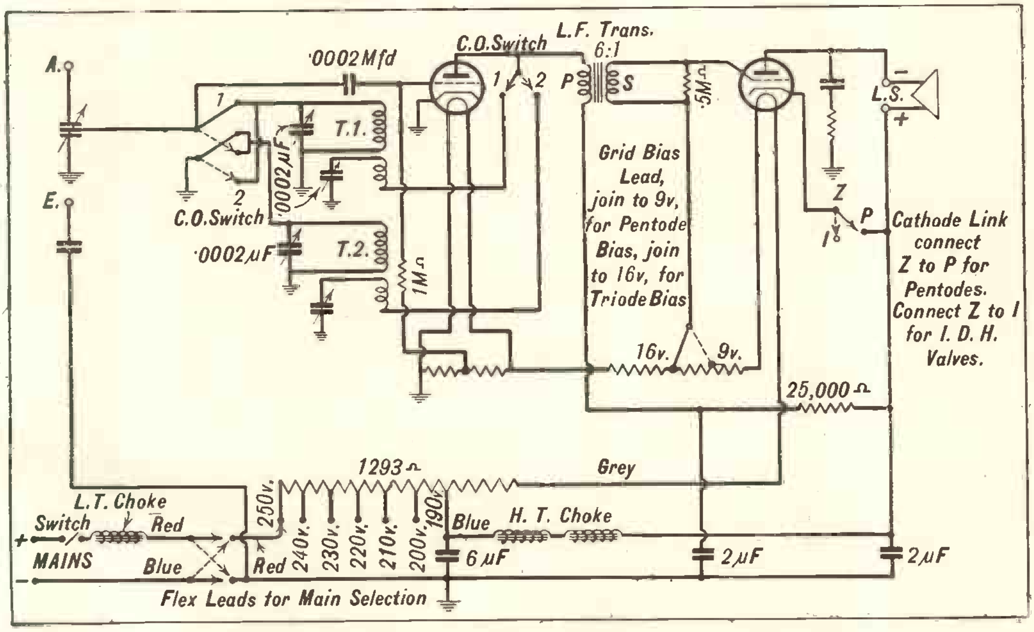


Fig. 25.—Theoretical Circuit Diagram of Columbia 309 D.C. Receiver.

MODEL 307 D.C.

Similar chassis and method of mounting as 307 A.C., but the valves are parallel connected with suitable resistances in series with each valve to obtain correct bias. An external resistance is used to supply correct filament current, the three connecting leads being : red, mains voltage adjuster ; blue, H.T. to receiver ; grey, L.T. to receiver.

Note.—Aerial tuning circuit and inter-valve transformer secondary are connected to chassis because of method of obtaining bias.

Operating Data

Emission
- S.G. valve . . . . 0·3–1 m.a.
- Detector valve (right, front)
  - Radio . . . . 2–4 m.a.
  - Gram. . . . . 2–4 m.a.
- Pentode valve (right, back) . 12–15 m.a.

Voltages

L.T.	Across filaments .	4	volts
H.T.	S.G., chassis to anode .	100–110	,,
	S.G., chassis to screen .	65–75	,,
	Detector, chassis to anode. Radio .	50–60	,,
	Gram. .	60–70	,,
	Pentode, chassis to anode . . .	135–145	,,
	Pentode, chassis to screen . . .	150–160	,,
G.B.	S.G.	3	volts
	Pentode . . .	10	,,
	Detector on Gram. .	3	,,

MODEL 308

A four-valve radiogramophone only in A.C. The receiver consists of Model 307 A.C. with an extra L.F. added. Only L.F. and power valves are used on gram, and the first L.F. transformer is switched over for use as pick-up transformer, enabling same volume control to be used for both radio and gram. A radio intensifier consisting of a 500,000 ohm potentiometer across aerial circuit is used for radio only.

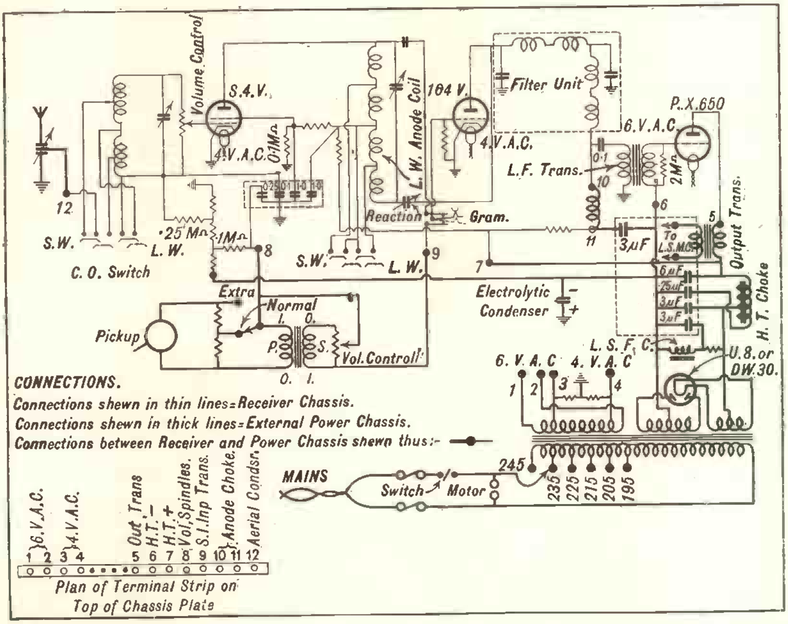


Fig. 26.—Theoretical Circuit Diagram of Columbia 310 Receiver.

Removing Chassis from Cabinet

To remove the chassis from the cabinet, remove the lid stay and arrange to support the lid or remove altogether. Then take off the four battens around the sides of the motor boards. Disconnect mains leads from motor and earthing tag and disconnect the pick-up leads on the pick-up transformer. Unscrew the motor board and lift out. Now take off all control knobs on front of the instrument and also the escutcheon. Remove the differential aerial condenser knob and loosen this

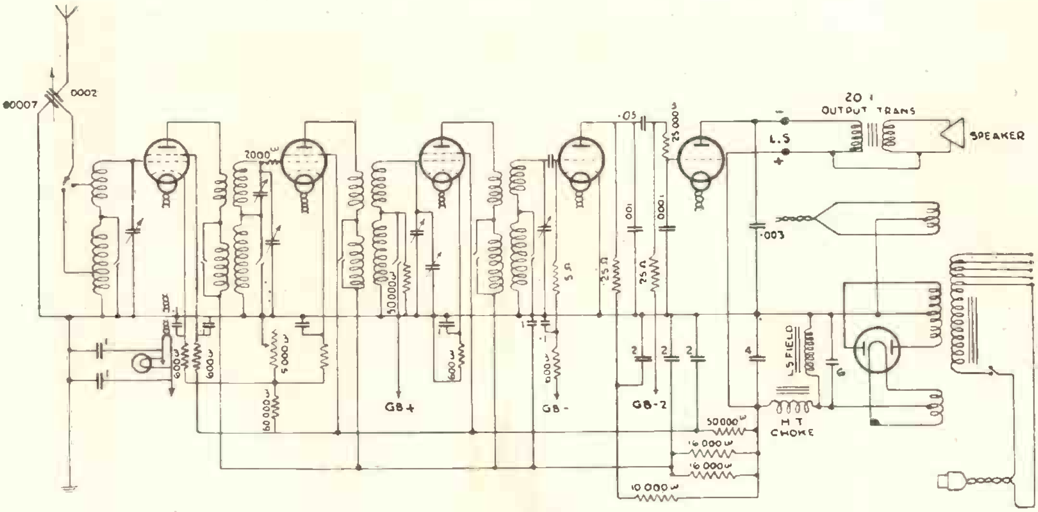


Fig. 27.—Theoretical Circuit Diagram of Columbia 333 Receiver.

condenser on the chassis, removing front fixing nut and insulating washer when the condenser can be slid inwards to clear the side of the cabinet. Disconnect speaker leads and remove the four bolts holding the chassis to the runners when the chassis will withdraw.

Small terminal strips and four small bolts fasten the receiver chassis to the power unit after which proceed as for Model 307 A.C.

The rectifying unit and power amplifying unit are on the underside of the power shelf.

Operating Data

Emission

S.G. valve . . .	0·3–1 m.a.
Detector valve (right, front) .	2–4 m.a.
1st L.F. valve (right, back) .	8–10 m.a.
Power valve (left side platform looking from back) .	25–30 m.a.

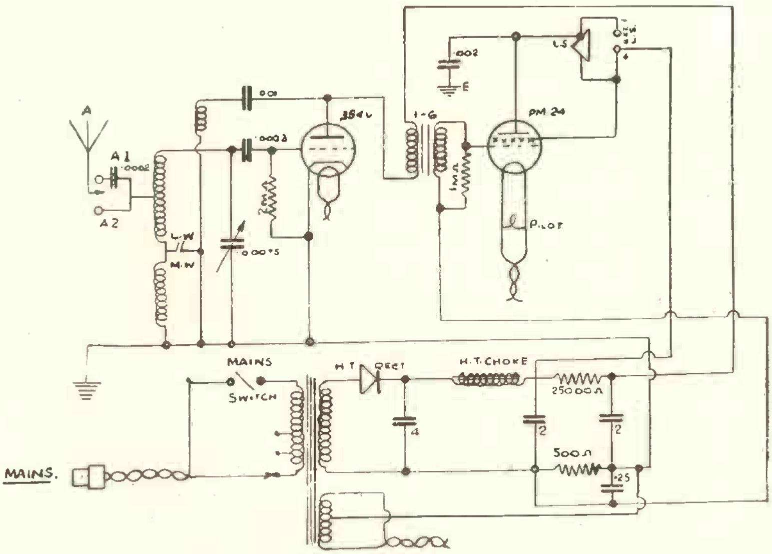


Fig. 28.—Theoretical Circuit Diagram of Columbia 350 Receiver.

Fig. 29.—REMOVING A COMPARTMENT FROM THE COLUMBIA 302 AND 304 RECEIVERS.

The compartment is removed complete with medium wave coils behind switch contact and long wave coils on top. Binocular coils are employed to reduce stray field.

Voltages

L.T.	Across heaters of S.G. detector, L.F.	4 volts A.C.
	Across fil. of power	7·5	,,
	Across fil. of rectifier	7·5	,,
H.T.	S.G., between chassis and anode	155–165 volts	
	S.G., between chassis and screen	95–105	,,
	Detector, between chassis and anode	40–50	,,
	1st L.F., between chassis and anode	140–150	,,
	Power, between chassis and anode	370–390	,,
G.B.	S.G.	3	,,
	L.F.	4·5	,,
	Power	30	,,

MODEL 309 BATTERY

Similar receiver to 309 A.C., but using 2-volt battery valves.

Operating Data

Emission

Detector valve	1·5–2 m.a.
Pentode valve	6–8 m.a.

Voltages

L.T.		2 volts.	
H.T.	H.T.1	84	,,
	H.T.2	120	,,
G.B.	Between G.B. + and G.B. —	9	,,

Fig. 30.—METHOD OF REMOVING VALVE HOLDER IN DETECTOR COMPARTMENT.

Showing resistance capacity stage.

Fig. 31.—RELEASING THE CHASSIS SCREWS OF THE COLUMBIA 352 RECEIVER.

This is done after taking off control knobs.

MODEL 309 A.C.

This is a twin-station receiver employing two sets of plug-in coils, two tuning circuits with reaction and a switch to select either station. The tuning and reaction knobs are situated under the front escutcheon plate.

A metal rectifier is employed for half-wave rectification, and the circuit is a detector, transformer coupled to pentode. Provision is also made for using triode power, or I.D.H. power, or I.D.H. pentode.

To take the chassis out of the cabinet, release the speaker leads from the chassis, and take out the four bolts which hold it to the floor of the cabinet, when the chassis will withdraw complete.

Operating Data

Emission
- Detector valve 1·5–2 m.a.
- Pentode valve 12–15 m.a.

Voltages

L.T.	. . . .	4 volts A.C.
H.T.	Detector, between chassis and anode .	60–80 volts
	Pentode, between chassis and anode .	115–120 ,,
	Pentode, between chassis and screen .	120 ,,
G.B.	Between G.B. + and G.B.1 . . .	7½–9 ,,

MODEL 309 D.C.

Similar to Model 309 A.C.; the mains resistance being internal, and no grid battery.

Chassis withdrawal procedure as for 309 A.C.

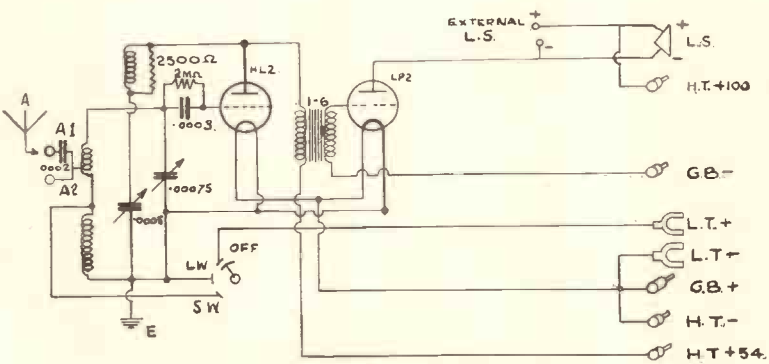


Fig. 32.—THEORETICAL CIRCUIT DIAGRAM OF COLUMBIA 351 RECEIVER.

Fig. 33.—WITHDRAWING THE CHASSIS OF THE COLUMBIA 352 RECEIVER.

Operating Data

Emission		
Detector valve	1–1·5 m.a.	
Pentode valve	14–17 m.a.	
Voltages		
L.T.	4	volts
H.T. Detector, between chassis and anode	60–80	,,
Pentode, between chassis and anode	150–160	,,
Pentode, between chassis and screen	160	,,
G.B. Between chassis and – 9-volt terminal (change to – 16 if triode used)	9	,,

MODEL 310 A.C.

A three-valve radiogram employing the receiver chassis of Model 307 A.C., but a 6-volt super-power valve in output stage, and the intervalve transformer is choke capacity fed.

To take out the radio chassis it is necessary to take out the motor and also the amplifier deck. Unscrew the fillets around the motor board and take out the motor board screws; release the motor supply leads from the side of the cabinet and from the three main terminals on the right of the amplifier panel. Take the pick-up leads off terminals 8 and 9 (remembering the correct leads) and the motor board will lift out.

Next disconnect the A and E leads from the amplifier deck, also the speaker field and speech leads from under the deck. Take off the intensifier and reaction knobs and withdraw the four bolts which hold the amplifier deck to the two runners, when the deck will draw out.

The receiver chassis is screwed down to the amplifier board in addition to the twelve connecting strips, and after these have been removed the chassis will lift off. The rectifying and power amplifying unit are on the under side of the power shelf. For further particulars see 307 A.C.

Operating Data

Emission	
S.G. valve	0·3–1 m.a.
Detector valve (right, front)	
Radio	3·5–4·5 m.a.
Gram.	3–3·5 m.a.
Power valve (right, back)	30–35 m.a.
Speaker field	30 m.a.
Voltages	
L.T. Across heaters of S.G. and detector	4 volts A.C.
Across filament of power	6 ,,
Across filament of rectifier	7·5 ,,

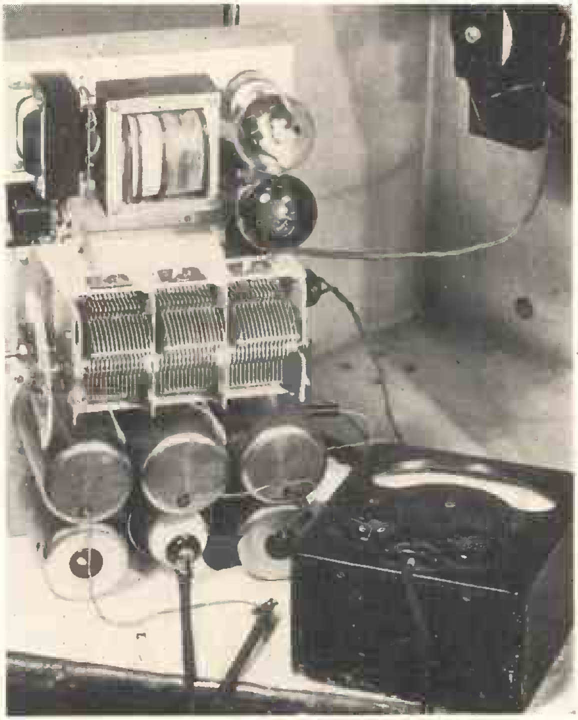


Fig. 34.—Carrying out Tests on Columbia 352 Receiver.

With chassis out of cabinet and loud speaker in cabinet.

H.T.	S.G., between chassis and anode	110–120	volts
	S.G., between chassis and screen	80–100	,,
	Detector, between chassis and anode.		
	Radio	50–60	,,
	Gram.	80–90	,,
	Power, between chassis and anode	200–220	,,
	L.S. field to chassis	180–200	,,
G.B.	S.G.	3	,,
	Detector (gram.)	4·5	,,
	Power	30–35	,,

MODEL 310 D.C.

Similar to 310 A.C., but arranged for D.C. operation, the mains resistance being situated on the floor of the cabinet. The mains adjusting lead is red, H.T. to receiver blue, L.T. to receiver grey and these must be disconnected before the chassis can be removed.

The field coil of this M.C. speaker is of low resistance, about 25 ohms, and is connected in series with the filament circuit.

A grid bias battery is fitted to provide bias for the power valve.

Operating Data

Emission		
S.G. valve		0·3–1 m.a.
Detector valve (right, front)		
Radio		2–4 m.a.
Gram.		1–2 m.a.
Power valve (right, back)		25–30 m.a.
Voltages		volts
L.T.	S.G. and detector	4
	Power	6
H.T.	S.G., between chassis and anode	125–135
	S.G., between chassis and screen	70–80
	Detector, between chassis and anode	
	Radio	100–110
	Gram.	150–160
	Power, between chassis and anode	160–170
G.B.	Between G.B. — and chassis	26
	(18 battery + 8 mains)	

MODELS 331 AND 332

These models contain a 307 chassis and 325 speaker in pedestal cabinet.

Fig. 35.—Trimming the Gang Condensers on Columbia 352, 603 and 604 Receivers.

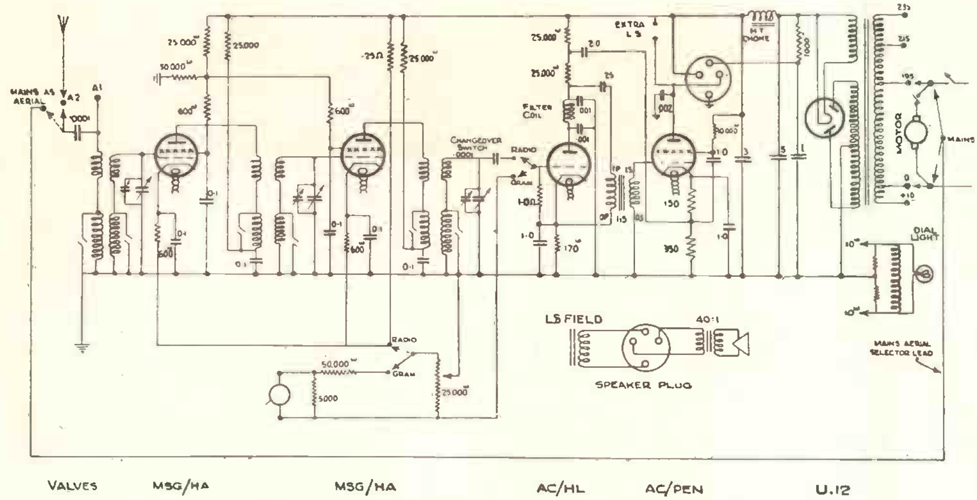


Fig. 36.—Theoretical Circuit Diagram of Columbia 352 A.C. Receiver.

MODEL 333

This model contains a 304 I.D.H. chassis with moving-coil speaker, energised from the same rectifier. The receiver is housed in a walnut pedestal cabinet with two doors.

MODEL 325

A balanced armature speaker with tapped coil for triode or pentode power valve.

MODELS 326, 327

A moving-coil energised speaker with 20/1 ratio transformer or direct connection to speech coil.

MODEL 350 A.C.

A two-valve receiver; detector, and pentode power valve using half-way metal rectifier. Resistances in the filament leads of the power valve make a 2-volt valve suitable.

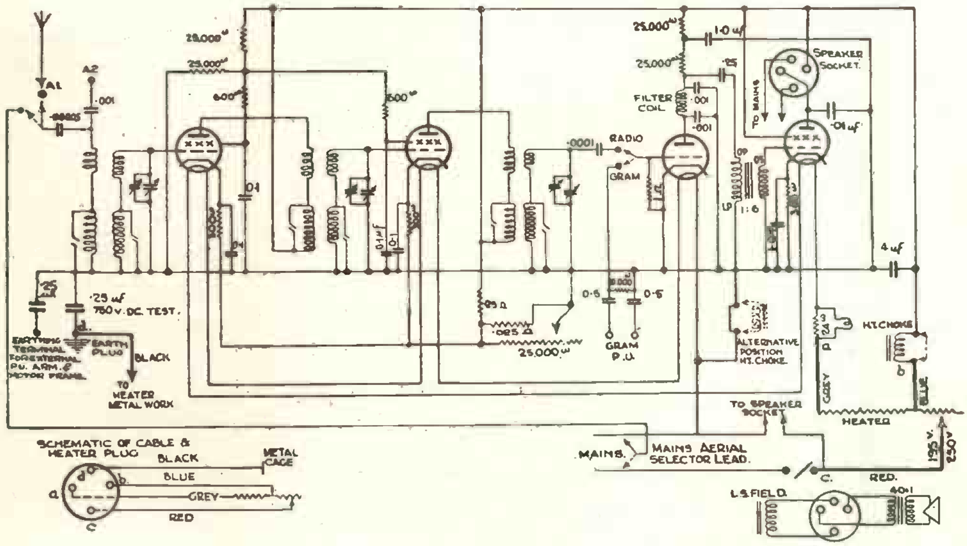


Fig. 37.—Theoretical Circuit Diagram of Columbia 352 D.C. Receiver.

Fig. 38.—Coil Cover removed from Columbia 352, 603, and 604 Receivers.
Showing switch contacts.

To remove the chassis, take off the switch and reaction knob ; the lead from the mains switch, four wood screws which hold the chassis to the face of the cabinet, and two metal screws which fix the chassis to the shelf. The chassis can now be withdrawn for test and the speaker leads unsoldered if necessary.

Operating Data

Emission	
Detector valve . .	1–2 m.a.
Pentode valve . .	10–13 m.a.
Voltages	volts
L.T. Detector .	4
Pentode . .	2
H.T. Detector between chassis and anode .	50–60
Pentode, between chassis and anode . .	105–115
Pentode, between chassis and screen . .	110
G.B. Pentode, between chassis and bottom end of intervalve transformer .	6

MODEL 350 D.C.

Similar chassis to 350 A.C., the mains resistance is mounted inside at the back.

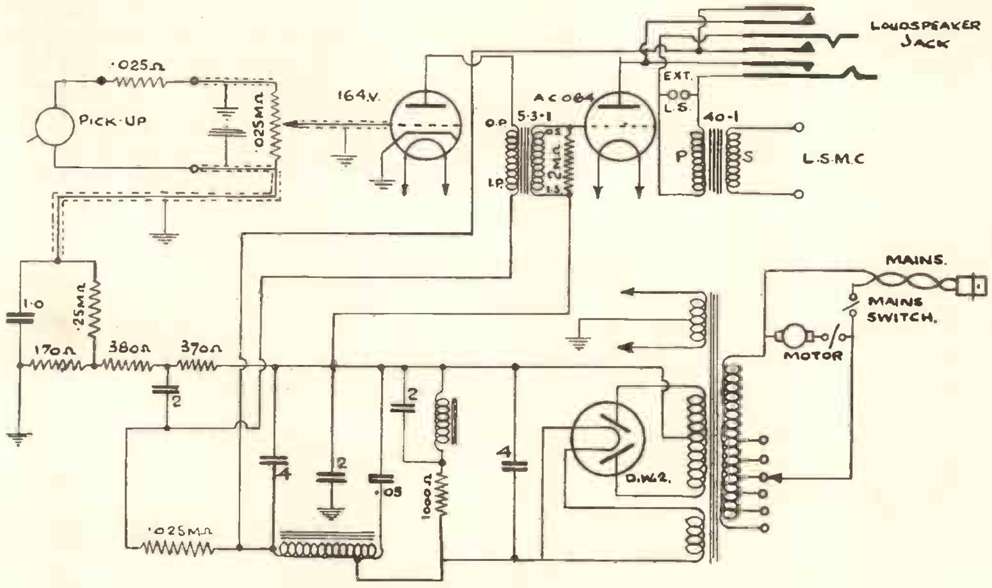


Fig. 39.—Theoretical Circuit Diagram of Columbia 500 A.C. Receiver.

Operating Data

Emission
- Detector valve . . . 3–4 m.a.
- Pentode valve . . . 7–10 m.a.

Voltages
- L.T. Detector . . . 4 volts
- Pentode . . . 2 ,,
- H.T. Detector, between chassis and anode . 50–60 ,,
- Pentode, between chassis and anode . 160 volts
- Pentode, between chassis and screen . 160 ,,
- G.B. Pentode, between filament and bottom end of intervalve transformer . 5 ,,

MODEL 351

A two-valve battery receiver using detector and triode power valve. To remove the chassis, take off the tuning, reaction and switch knobs, unscrew the A and E panel, take out the battery support bar and speaker cone, and disconnect the speaker leads. Unscrew the four wood screws holding the chassis to the front of the cabinet and the chassis will be released.

Operating Data

Emission
- Detector valve . 0·5–1 m.a
- Power valve . . 4–6 m.a.

Voltages
- L.T. . . . 2 volts
- H.T. H.T. + . 54–60 ,,
- H.T. + 100 . 99 ,,
- G.B. G.B. – . 3–4½ ,,

MODEL 352 A.C.

A four-valve receiver using two stages of H.F. with detector resistance capacity coupled transformer to pentode. All are I.D.H. valves.

To remove the chassis take off the volume, tuning and range switch knobs; take out the speaker plug and also the four bolts which hold the chassis in position; it will then lift out. If only the speaker requires service this can be taken out independently by removing the four bolts holding it to the cross-bars. Modulation hum on radio can often be cured by fitting 10,000-ohm resistance across the pick-up sockets.

Operating Data

Emission
- Front S.G. valve (vol. control max.) . . . . 2–3 m.a.

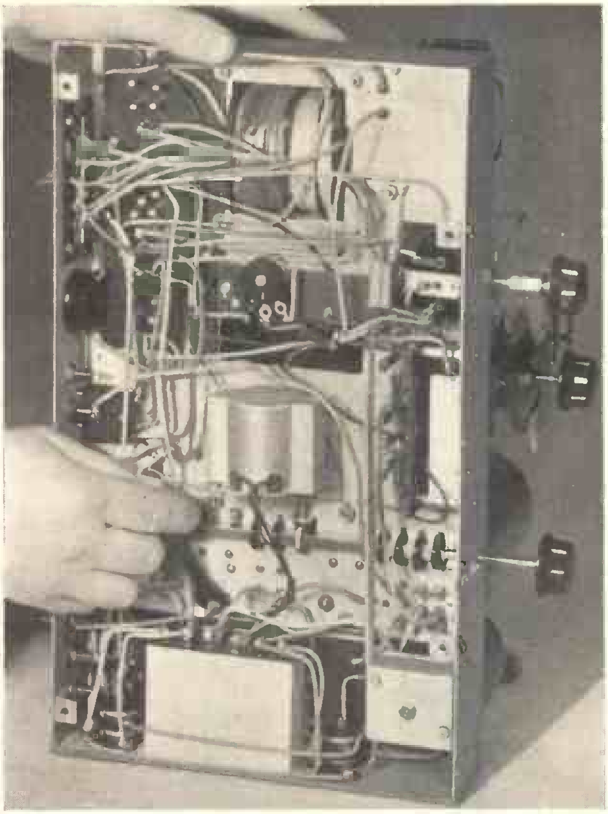


Fig. 40.—UNDERSIDE OF CHASSIS OF COLUMBIA 352, 603 AND 604 RECEIVERS.

Showing method of releasing can cover nuts. De-coupling condenser bank and bias resistances on right. Field resistance near mains adjusting strip.

- Centre S.G. valve (vol. control max.) . . . 2–3 m.a.
- Back detector valve
  - Radio . . . . 3–4 m.a.
  - Gram. . . . . 3–4 m.a.
- Pentode . . . . 20–25 m.a.

Voltages
- L.T. All receiving valves . 4 volts
- Rectifying valve . 4 ,,
- H.T. Front S.G., between chassis and anode . 180–200 ,,
- Front S.G., between chassis and screen . 120–130 ,,

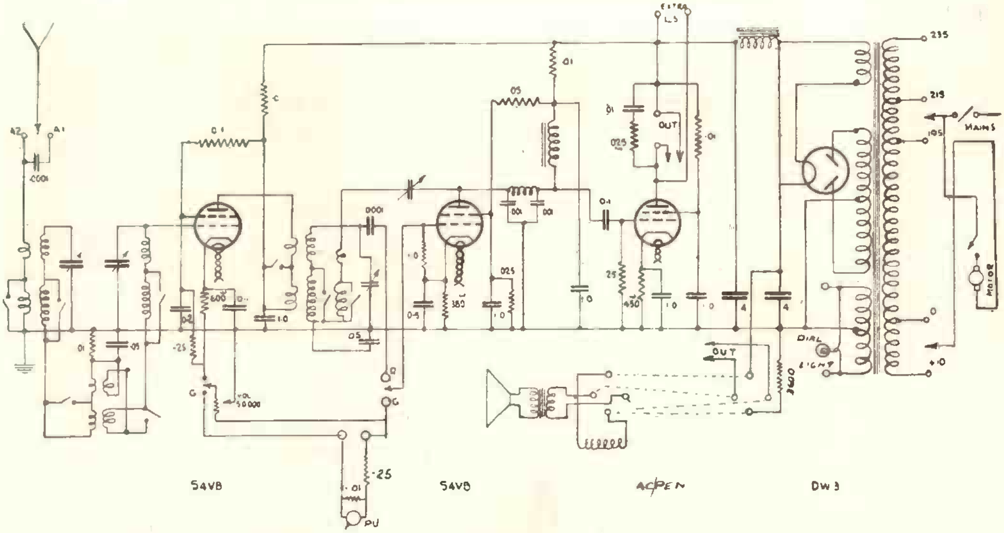


Fig. 41.—Theoretical Circuit Diagram of Columbia 602 A.C. Receiver.

	Second S.G., between chassis and anode	180–200	volts
	Second S.G., between chassis and screen	120–130	,,
	Detector, between chassis and anode		
	Radio	65–75	,,
	Gram.	75–85	,,
	Pentode, between chassis and anode	250	,,
	Pentode, between chassis and screen	200	,,
G.B.	2 S.G. valves between chassis and volume control	2–15	,,
	Pentode, between chassis and cathode	15	,,

MODEL 352 D.C.

Similar to 352 A.C., but using D.C., I.D.H. valves ; the mains resistance being external, having connections as follows :—Red lead, adjustable mains lead ; blue, H.T. for receiver ; grey, L.T. to receiver.

The right-hand socket on the chassis is for the resistance plug connector, the socket between the pentode socket and the gang condenser is for the speaker plug. The chassis bolts, grub screws, etc., are filled with insulating material to prevent shocks.

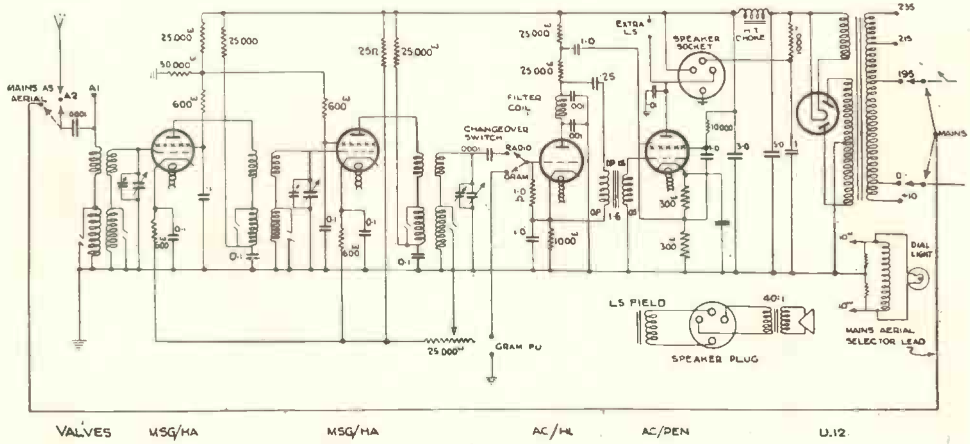


Fig. 42.—Theoretical Circuit Diagram of Columbia 603 A.C. Receiver.

Operating Data

Emission		
Front S.G. (vol. control max.)	4–6 m.a.	
Centre S.G. (vol. control max.)	4–6 m.a.	
Detector. Radio	2–4 m.a.	
Gram.	2–4 m.a.	
Pentode	25–30 m.a.	
Voltages		
L.T. S.G. S.G. detector	6	volts
Pentode	8	,,
H.T. Front S.G., between chassis and anode	180–200	,,
Front S.G., between chassis and screen	50–60	,,
Centre S.G., between chassis and anode	180–200	,,

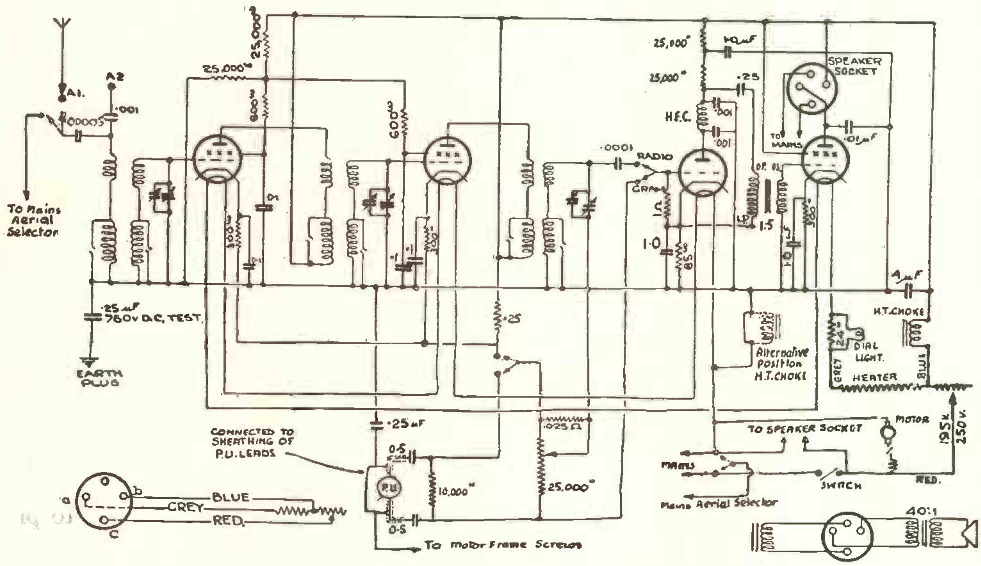


Fig. 43.—THEORETICAL CIRCUIT DIAGRAM OF COLUMBIA 603 D.C. RECEIVER.

Centre S.G., between chassis and screen	50–60	volts
Detector, between chassis and anode	40–50	,,
Pentode, between chassis and anode	170–180	,,
Pentode, between chassis and screen	180–200	,,
G.B. 2 S.G. valves, between chassis and volume control	2–15	,,
Pentode, between chassis and cathode	12	,,

MODEL 500

This is an electric gramophone using an I.D.H. amplifying valve and triode power valve. The speaker can be used alone in connection with a radio receiver.

To remove the amplifying panel from the cabinet take off the combined switch and volume control knob, and release the leads from under cleats, also the plate holding the volume control unit. Take out the four bolts from under the amplifier shelf leaving the iron straps in position, and the amplifier, complete with speaker, will lift out. The jack can be unscrewed from the side of the cabinet.

Operating Data

Emission		
L.F. valve	3–5 m.a.	
Power valve	18–22 m.a.	
Voltages		
L.T. L.F. and power	4	volts
Rectifier	4	,,
H.T. L.F. valve, between chassis and anode	100–110	,,
Power valve, between chassis and anode	190–200	,,
G.B.	20–25	,,

MODEL 602 A.C.

A three-valve radiogramophone using band-pass prior to H.F., and a S.G. detector which is choke capacity coupled to a pentode power valve. All I.D.H. valves. The top or first S.G. valve is the detector valve.

To take the chassis out remove the fillets around the motor board, and also

Fig. 44.—How to remove the Loud Speaker from the Cabinet of the Columbia 352 Receiver.

the lid stay by taking out the spring clip which holds the pin in the lid stay hinge. Support the lid. Remove the motor board screws, unscrew the A.E. panel and cleat holding wires from the cabinet, disconnect the mains lead from the motor at the motor terminals, disconnect the two pick-up leads and earthing clip. Remove the three knobs from the top of the cabinet, also the volume control knob from the front. A cleat holds the mains lead, remove this and the four bolts from under the platform holding the chassis in position. The motor board will now lift out and the chassis will withdraw.

If testing the chassis out of the cabinet, be careful to insulate the motor mains leads.

Operating Data

Emission		
	Top S.G. valve, detector	2–3 m.a.
	Centre S.G. valve, H.F. (vol. control max.)	2·5–3·5 m.a.
	Bottom A.C. pentode valve	25–30 m.a.
Voltages		
L.T.	All receiving valves	4 volts A.C.
	Rectifying valve	4 ,,
H.T.	Top S.G., between chassis and anode	190–200 volts
H.T.	Top S.G., between chassis and screen	55–65 volts
	Centre S.G., between chassis and anode	195–215 ,,
	Centre S.G., between chassis and screen	90–100 ,,
	Pentode, between chassis and anode	255–265 ,,
	Pentode, between chassis and screen	200–210 ,,
G.B.	H.F., between chassis and volume control	2–15 ,,
	Pentode, between chassis and cathode	10–13 ,,

MODEL 602 D.C.

The chassis is similar to 602 A.C. D.C., I.D.H. valves are used, and the mains resistance is situated on the back of the cabinet. The mains adjusting lead is red, H.T. blue, L.T. grey, and the right-hand socket on the chassis is for the resistance plug. Be careful to keep the screened leads of the pick-up clear from the condenser vanes, as on positive earth mains there is the full mains voltage between chassis and earthed screened leads. If bad mains hum is experienced try connecting the pick-up and/or motor resistance leads through a 0·25 mfd. condenser to either chassis or earth.

Fig. 45.—Centering the Loud Speaker Cone.

Operating Data

Emission			
	Top S.G. valve, detector	4 m.a.	
	Centre S.G. valve, H.F.	0–8 m.a.	
	Pentode valve	18–22 m.a.	
Voltages			
L.T.	S.G. and S.G. detector	6	volts
	Pentode	8	,,
H.T.	Top S.G., between chassis and anode	95	,,
	Top S.G., between chassis and screen	50–60	,,
	Centre, between chassis and anode	180	,,
	Centre, between chassis and screen	80–100	,,
	Pentode, between chassis and anode	180	,,
	Pentode, between chassis and screen	190	,,
G.B.	H.F., between chassis and volume control	2–15	,,
	Pentode, between chassis and cathode	9–12	,,

MODEL 603 A.C.

This radiogram has the same chassis as Model 352 A.C with an extension for tuning.

To remove the chassis, take out the motor board screws, release motor earth lead on the choke on chassis, take off wave-change knobs, and the motor board will lift off.

Withdraw the speaker plug, pick-up plugs, release the volume control and switch by unscrewing the four wood screws holding the plate. Disconnect the tuning spindle near the clutch; it is fastened by a small grub screw. Take out the four bolts holding chassis to platform and the chassis can be lifted out. When replacing this chassis it is necessary to replace the washers; this is best done by placing washers on the bolts and placing the bolts in position in the chassis; then place the chassis in position by lowering the bolts through the holes. Withdraw each bolt singly and refix with the large washer underneath.

Operating data similar to Model 352 A.C.

MODEL 603 D.C.

A radiogram with chassis similar to Model 352 D.C. and general details as for Model 603 A.C. The resistance element is situated on the floor of the cabinet.

COLUMBIA GRAMOPHONE AUTOMATIC STOP

The Columbia automatic stop for turntables is fitted on all Columbia radio and electric gramophones and operates as follows: The projection on the pick-up arm moves towards the side of the prongs which is covered to prevent mechanical knocks, and through a friction grip at the pivot of the prong arm an extension is moved towards the spindle of the motor. An ebonite bush with a friction grip is on the spindle, and as the extension mentioned comes within touching distance it is thrown back slightly for each record groove until a quick running groove is reached, when the extension is pushed well inside the ebonite cam, giving the extension a sharp thrust which pushes the switch open.

If the run off fails to switch the motor off, it is due either to the ebonite bush sliding round on the motor spindle, in which case the ring clip requires taking off and compressing; or possibly the switch itself has moved slightly, allowing the roller tip to come well over the hump on the blade of the switch. It is also possible for the friction grip at the pivot of the prong arm to be too slack, allowing the extension to be knocked too far each time it hits the ebonite bush.

When the motor switches off prematurely the cause is usually too great a friction grip at the pivot mentioned; this grip is adjusted by withdrawing the U-shaped spring washer and bending slightly.

COLUMBIA MODEL 450 PICK-UP

This is a gramophone pick-up and is employed on all Columbia radio and electric gramophones.

To test if the reed is out of adjustment scrape the thumb along the point of the needle and if the strength of this scrape is heard stronger in the loud speaker for one direction than the other, the reed is out of centre.

To recentre the armature or reed, it is necessary to remove the pick-up from between the jaws of the pick-up arm, either by releasing the pivots on the earlier models, or by compressing the spring which holds the pick-up on the pivots. The cover can be taken off after withdrawing the three screws.

The armature is centred by applying pressure to the two pieces of rubber on either side of the armature, the adjustable pressure being controlled by a cam on the underside of the milled washer, the cam resting inside the thin washer which has a lip projecting down behind the rubbers.

Above this milled washer, the bar and nuts hold the whole in position, so it is necessary to take some pressure off the bar by releasing the nuts, when the milled washers can be adjusted.

Should the rubber covering over the pick-up armature pivot be perished it is necessary to pull down completely by removing first the pick-up magnet, then the leads and lastly the two front screws, when the coil and pole pieces will be released.

The two pole pieces will part company, and after cleaning new rubber tubing can be forced on. When reassembling remember the order in which taken off, which is : thin washer with projecting lip, milled cam washer, bar, spring washer, nut. Hold the pick-up face downwards when replacing the cover or the back nut may fall out of its receptacle.

FINDING THE BEST POSITION FOR A WIRELESS SET

When deciding on the best position for a set in a room care should be taken to see that no great difficulty will be experienced in connecting to the aerial and earth wires. If a mains set, consideration must be given to making contact with the most convenient source of supply.

Usually in the corner of a room fairly near a window will be found suitable. See that the set is not placed in a position where the sun's rays are direct on it, or where it might suffer damage if a window were accidentally left open. Neither should it be placed near a heat radiator or hot-water pipe. Make sure that the tuning dials can be easily seen.

Position of the Loud Speaker

Most satisfactory results will be obtained if the loud speaker is placed so that it comes nearly level with the head, *i.e.*, about $5\frac{1}{2}$ feet from the ground. This helps the reproduction to sound crisp and natural. A corner position is best because the reflection from the adjacent walls will help to throw the sound into the room.

The back of the loud speaker cabinet, if of the cone or moving-coil type, should not be placed against the wall or any solid object. There must be an air space behind the back, if good reproduction is to be obtained. Some loud speakers, however, are made so that they can be hung on the wall from the picture rail.

Don't stand the loud speaker on top of the set or on top of a piano. In the first case it may cause the valves to become microphonic, while in the second, the strings of the piano may be caused to vibrate. When a set has the loud speaker incorporated in the cabinet it will be found that the set is definitely built to withstand any such vibration.

Sometimes on a certain note rattle may be caused by a vibrating object, such as a vase or ash-tray in the room. Moving the object to another position will often effect a cure.

HIGH-FREQUENCY CHOKES

By FRANK PRESTON, F.R.A.

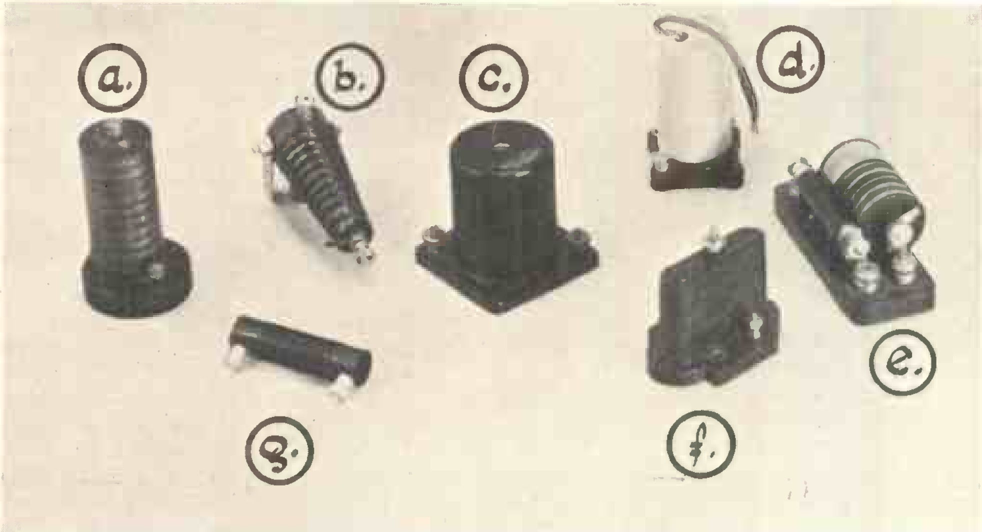


Fig. 1.—A Few Typical Examples of High-frequency Chokes.

(*a*) Wearite high-inductance choke ; (*b*) Eddystone " Universal " (long and short wave) choke ; (*c*) Dubilier H.F. choke ; (*d*) Wearite screened choke ; (*e*) Graham Farish choke-capacity H.F. coupling unit ; (*f*) Lotus binocular choke ; (*g*) Eddystone ultra short-wave choke.

A H.F.C. in Detector Anode Circuit

THE best known use of a high-frequency choke (in future we will refer to it by the popular abbreviation of " H.F.C.") is in the anode circuit of a detector valve with which reaction is obtained by means of a fixed reaction coil and a variable condenser. For convenience a skeleton circuit of the arrangement is given in Fig. 2.

High Inductance

In the first place the choke should offer uniform resistance (or more correctly, impedance) to the frequencies represented by all the wavelengths to which our receiver can be tuned. The latter generally extends from about 200 to 2,000 metres. To obtain this result entails that the natural wavelength of the choke should be well in excess of 2,000 metres and, as a matter of fact, the best results are generally obtained by designing the choke so that it resonates at a wavelength in the region of 4,000 metres.

This in turn makes it necessary to use a very large number of turns of wire and explains why the better-class chokes are somewhat expensive.

Cause of Inefficiency on Long Waves

The same explanation shows why many receivers are inefficient on the long waveband though quite satisfactory on medium waves. The choke employed has too low an inductance to be effective on long waves although its inductance is sufficient to provide the necessary " stopping " effect on lower wavelengths. Incidentally, it might be added here that the fault just mentioned can usually be distinguished from the fact that above a certain wavelength the reaction control has to be advanced well beyond its normal setting. It also sometimes happens that a low-priced choke actually resonates (tunes) to a wavelength on the long waveband. As a result, reaction is unsatisfactory above and below a certain wavelength. Just *at* that wavelength, however, it is particularly strong and generally "fierce," or difficult to control.

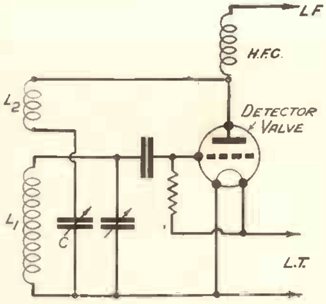


Fig. 2.—USE OF H.F. CHOKE IN ANODE CIRCUIT OF DETECTOR VALVE WITH REACTION.

Low Capacity

In addition to possessing a high inductance value a good choke should also have a very low self-capacity because, if high, the capacity would permit of leakage of high-frequency currents across it. The capacity might also in some cases make the choke tune sharply to a particular wavelength instead of having the required even response to a wide band of wavelengths.

With the object of cutting down capacity the windings are usually divided into a number of sections as shown in the sketch of Fig. 7.

Low D.C. Resistances

A good choke should also, for many purposes, have a low resistance to D.C. currents. This means that it must be wound with comparatively heavy gauge wire, which again means increased cost.

Other Uses of H.F. Chokes

So far we have considered H.F. chokes only in relation to their function as "stoppers" in the anode circuits of regenerative detector valves, but they have a considerably wider field of utility than this, as can be judged by examining the circuits of Figs. 3, 4, 5 and 6.

Let us first look over the arrangement depicted by Fig. 3. This is a skeleton circuit of an S.G.-D.-P. A.C. receiver—the power supply circuit has been omitted for simplicity.

The choke marked "*c*" is the one we have already considered. Choke "*b*" acts in a rather similar manner and its function is to prevent the signal currents in the anode circuit of the S.G. valve from following the path indicated by the dotted arrow into the high tension supply circuit. By doing so the currents are compelled to pass into the tuning circuit of the detector valve by the path marked with full-line arrows.

A choke for this position must be as near as possible to the ideals we have previously established. Its impedance at all wavelengths must be high in relation to that of the screened-grid valve. This means that it must have an inductance (which is in effect a measure of the impedance) of no less than 200,000 microhenries. At the same time the self-capacity should not exceed some 4 micro-microfarads.

As the choke is virtually in parallel with the tuned grid coil L.2 it would damp the tuning of the latter if its impedance were too low. In addition, the amplification afforded by the S.G. valve would be reduced if the impedance of the choke were not in excess of that of the valve.

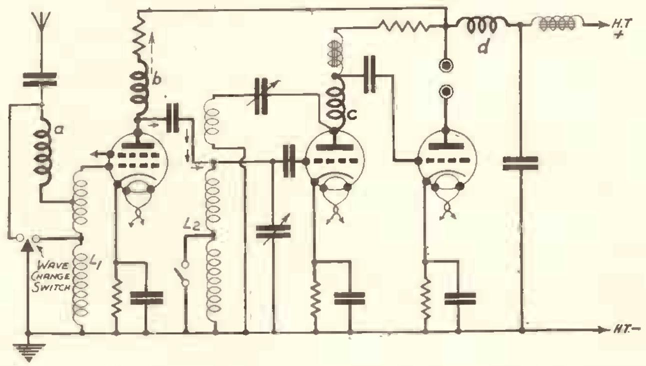


Fig. 3.—SKELETON CIRCUIT OF S.G.-D.-P. A.C. RECEIVER. Showing where H.F. chokes are required (shown as heavy lines).

Medium Wave Stopper

The choke marked "*a*" is a medium wave "stopper" and its function was mentioned in a previous article dealing with tuning coils. The choke must have a natural wavelength lower than the lowest wavelength covered by the long wave coil (generally about 1,000 metres), and higher than the highest wavelength of the medium wave coil (550 metres approximately), so that it will offer an equal impedance to all signals on the medium waveband.

A Choke in the H.T. Feed

Choke "*d*" is not often employed but is very useful in some cases of instability and unsteady reaction control. It prevents any "stray" H.F. currents from passing into the power supply.

A choke for this position does not require to have a particularly high inductance but must be capable of carrying the total anode current of all three valves. A special component for this purpose is made by Messrs. Wearite and one or two other firms.

Similar chokes can also often be used to advantage in the mains supply leads, particularly in the leads to a D.C. eliminator employed for H.T. supply only.

Other chokes of the same type, but capable of carrying currents up to ·6 ampere, are also available for connecting in the mains leads to an all-A.C. or an all-D.C. receiver.

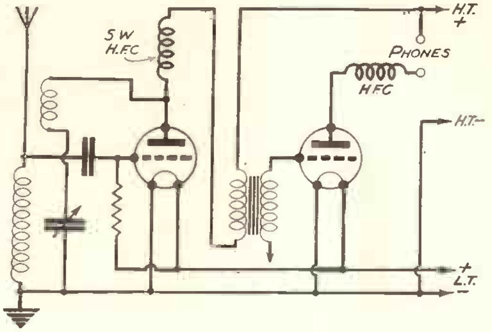


Fig. 4.—Two Uses for Chokes in a 2-Valve Short-wave Receiver.

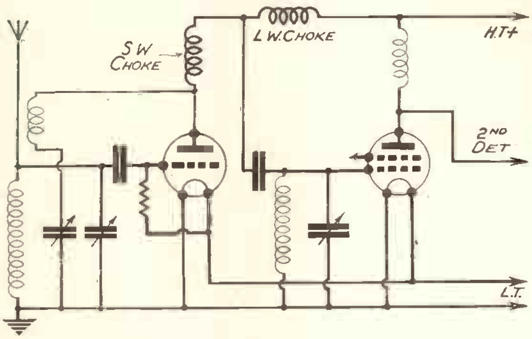


Fig. 5.—H.F. Chokes in a Short-wave Superheterodyne.

It is not generally necessary to connect chokes in the mains supply leads but they are exceedingly useful in cases where high-frequency apparatus is operated from the mains, for this often superimposes a H.F. "ripple" on the mains supply. This is usually indicated by a "bubbling" or "rippling" sound in the speaker.

Before trying the chokes, however, disconnect the aerial to make sure that interference is not being picked up from some outside source.

Short-Wave Chokes

A different kind of choke is required in a short-wave receiver of the type shown in the circuit of Fig. 4.

The choke marked "S.W.H.F.C." acts in the same way as that indicated at "*c*" in Fig. 3, but has to deal with much higher frequencies and therefore requires to have a correspondingly lower inductance. Its

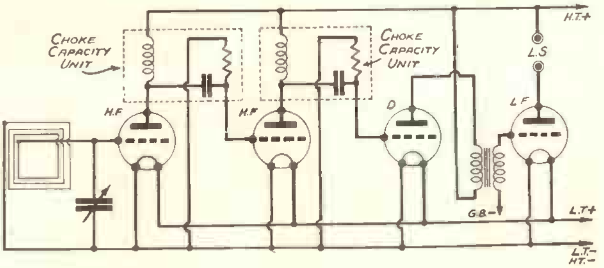


Fig. 6.—Circuit of a Choke Capacity Coupled H.F. Amplifier.

self-capacity must also be as low as ever possible because unwanted capacity is much more detrimental in a short-wave receiver.

Short-wave chokes are generally made similar to that shown in Fig. 9, and at "*g*" in Fig. 1. To keep down capacity the winding is put in a single layer on a thin ebonite tube and the turns are spaced.

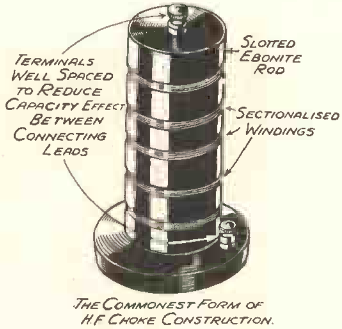


Fig. 7.—Commonest Form of H.F. Choke Construction.

Preventing "Hand-Capacity"

Another use for a H.F.C. is illustrated by Fig. 4. When using phones with a short wave receiver it often happens that hand-capacity effects are very troublesome and that "howls" and "squeaks" are heard when the phones are touched. This is due to stray H.F. currents leaking into the phone leads, so the obvious remedy is to keep them in check by inserting a choke between the last valve and the phones. The choke should really be of the short wave type but very often one of the normal pattern will serve sufficiently well.

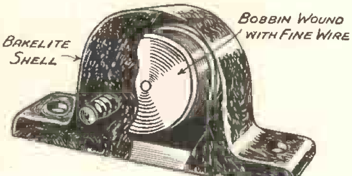


Fig. 8.—Design of Low-priced Choke Suitable for Anode Circuit of a Detector Valve on Wavelengths between 200 and about 1,800 Metres.

Chokes in S.W. Superhets.

Fig. 5 shows the circuit of the first detector and intermediate-frequency amplifier of a short-wave superheterodyne. In this case a short-wave choke is used for the normal purpose of keeping H.F. currents out of the amplifier and a second (long wave) choke is used in conjunction with a tuned grid coil to couple the two valves together. This second choke has to deal with the "Beat frequency" which generally corresponds to a wavelength of 600 metres or so, and therefore any normal component will serve the purpose.

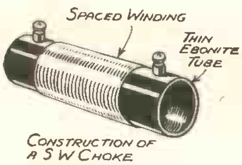


Fig. 9.—General Form of Construction for a Short-wave Choke.

Choke-Capacity Coupling

In some receivers, in which a high degree of efficiency is not called for, or where ease of tuning and low weight are primary considerations (in a portable, for instance), choke-capacity coupling is employed between the H.F. stages and between the H.F. and detector valves. A circuit of such an arrangement is shown in Fig. 6, from which it will be seen that the choke functions in exactly the same manner as "*b*" in Fig. 3.

One firm of manufacturers, Messrs. Graham-Farish, have made provision for this kind of coupling by supplying a complete choke-capacity coupling unit comprising of H.F. choke, grid condenser and grid leak. The latter is illustrated at "*e*" in Fig. 1.

The Second Detector

A number of firms, such as Messrs. Wearite, Bulgin and Dubilier, make a special choke for use in the anode circuit of the second detector valve of a superheterodyne. The latter valve has to deal only with a single frequency, that of the intermediate-frequency amplifier, and so the design

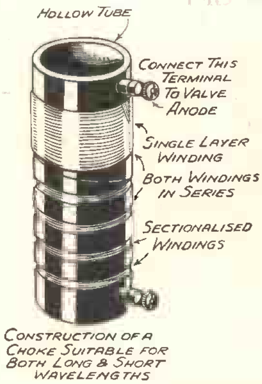


Fig. 10.—Construction of a Choke Required for both Long and Medium Wavelengths.

of a suitable choke is an easy matter. The frequency is generally about 110 kilocycles, which corresponds to a wavelength of approximately 2,700 metres, and in consequence a suitable choke must have a higher inductance than the normal type, but a little extra self-capacity does not matter.

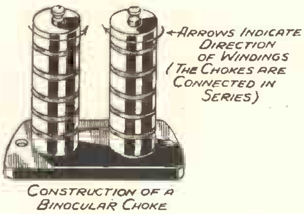


Fig. 11.—Construction of a Binocular Choke.

Forms of Construction

And now, having considered the principal uses of H.F. chokes, it will be interesting to see how they are made. The sketch of Fig. 7 shows the most common form of construction; the winding is divided into a number of sections so as to keep down self-capacity. A solid rod of ebonite with turned slots generally serves as former, but some makers replace the rod by a tube with a view to still further reducing capacity losses.

Chokes of the type represented by Fig. 7 are made by Messrs. Lewcos, Wearite, Goldtone, Dubilier, etc. A Wearite choke of this type is shown at "*a*" in Fig. 1, whilst a Dubilier can be seen at "*c*" in the same figure. The latter, it will be noticed is built into a bakelite moulding which serves to protect the windings.

Low-priced Chokes

Another well-known and popular type of choke is that shown in the sketch of Fig. 8. In this case the windings are put on a single bobbin of fairly large diameter. The self-capacity is somewhat higher than with other types of choke but the component is quite good enough for use in the anode circuit of a detector valve which is not required to operate on wavelengths above about 1,800 metres or below 200 metres. Chokes of this type are very popular and are made by Messrs. Lissen, Graham-Farish and others.

Short-Wave Chokes

The general construction of short-wave chokes has been dealt with before and is illustrated by Fig. 9.

"Dual-Range" Chokes

With a view to making the choke more suitable for covering both long and short wavelengths some manufacturers have adopted the excellent form of construction shown in Fig. 10. Here the winding is divided into two parts; the short wave portion is wound as a single layer to reduce self-capacity but the long wave winding is pile-wound in the usual manner in a number of slots. A Graham-Farish choke of this pattern is shown at "*e*" in Fig. 1.

Another choke designed on a similar principle is the "Eddystone," illustrated at "*b*" in Fig. 1. In this case all the windings are put in slots but as the ebonite former tapers towards one end the slots are of decreasing diameter, and in consequence contain decreasing lengths of wire; the smaller diameter windings have a smaller self-capacity.

In all chokes of the type just dealt with the "low capacity" end of the winding should be joined to the anode of the valve. By connecting in this way any capacity at the other end of the choke is of no consequence when dealing with short waves because the H.F. currents do not "penetrate" so far.

Preventing Inter-Action

Chokes, like tuning coils, have a magnetic field, and can therefore cause inter-action if placed near, and parallel to, other chokes or coils. Two methods of avoiding this difficulty are in common use. One is to divide the choke into two parts as shown in Fig. 11. As the windings on the two small chokes go in opposite directions the two magnetic fields tend to cancel each other.

Screened Chokes

Another way of preventing inter-action between chokes and other components is to build the chokes into screening cans. A screened choke (also having a screened "pigtail" for connecting to the anode of the valve) is shown at "*d*" in Fig. 1.

As the screening lowers the effective inductance, the windings must be designed to have an actual inductance in excess of the figure eventually required.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION VIII—TRANSFORMERS AND CHOKES

EVERY experimenter is well acquainted with transformers and chokes of several kinds. The former are so named by virtue of their function, which is to "transform" the electrical impulses supplied to them, so that either the voltage or the current is increased. The action of the choke is also described by its name: it "chokes," or holds back, the electrical impulses, or some of the electrical impulses, in the circuit in which it is situated.

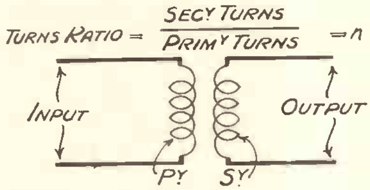


Fig. 1.—A Transformer with Two Coils very Close together.

Input and Output Circuits

The transformer has two circuits, the input circuit where the electrical energy is fed into the device, and the output circuit across the terminals of which the transformed energy is available. The transformer proper comprises an arrangement of inductance with induction coupling between the input and the output circuits. Usually the coupling is by the mutual induction between two coils, and this mutual induction causes the energy transfer from input to output circuit. It will be evident from this that only energy due to alternating current can be passed through a transformer, since steady direct current energy does not create an induction effect. A direct current of varying intensity is equivalent to a combination of direct and alternating currents, and hence can be classed as an alternating current for the purposes of its action in relation to a transformer. We shall deal with variable intensity direct currents when we discuss the action of the valve.

We have stated that the transformer amplifies *either* the voltage or the current. It cannot amplify both. This may be shown as follows. The power in an electrical circuit is measured by the product of the voltage E across the circuit and the current I in the circuit, or writing P as shorthand for power, we have :—

$$P = EIk \quad . \quad . \quad (1)$$

The power is in WATTS when E is in volts and I is in amperes ; k is a number with a value between 0 and 1.

What Designers of A.C. Electrical Apparatus Aim for

For D.C. circuits $k = 1$: in the case of A.C. circuits, k is called the POWER FACTOR of the circuit, and its greatest value is 1. The smaller k is the more power is wasted in the circuit. It is the object of designers of A.C. electrical apparatus to make the circuit efficient so that $k = 1$, or is nearly equal to 1. The circuit is then highly efficient. In A.C. circuits E and I are R.M.S. values of voltage and current, and not peak values. In the case of an A.C. valve filament circuit where there are three valves,

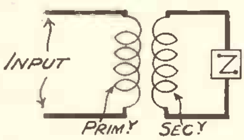


Fig. 2.—When the Transformer is connected in a Circuit the Effect on the Transformer is as if an Impedance or a Pure Resistance is connected across its Secondary Winding.

each taking 1 amp. of current at 4 volts, the power in the circuit is:

$$P = 4 \times 3 \times k \text{ watts.}$$

Such a circuit is usually highly efficient, and so, putting $k = 1$, we have :—

$$P = 12 \text{ watts.}$$

Now consider a transformer in which the input power is P, comprising voltage E across the input terminals and current I in the input circuit. Let the power factor be k. Then the relation (1) holds. Now suppose that the output voltage is $n \times E$, where n is greater than 1. Then the voltage has been amplified n times. Thus if the input voltage is 100 volts, and the output voltage is 240 volts, the voltage has been amplified 2·4 times—*i.e.*, $n = 2{\cdot}4$ in this case.

Why a Certain Amount of Input Energy is always Lost

It is one of the principles of science that energy of any sort cannot be created, magically, as it were. The power obtained from a machine (mechanical or electrical, etc.) can never be greater than the power put into the machine. Usually the machine is inefficient and wastes a considerable amount of the input energy, so that only a certain percentage is available at the output end. In a very well designed machine the losses can be made very small, and we shall suppose that in the case of the transformer we are treating now there is no energy loss between input and output. If the input power be 50 watts, then the output power is also 50 watts. Thus the output power of this transformer is P, and the power factor of the output power is assumed to be the same as that of the input, viz., k. Let us write i for the output current, then we have :—

Output power $= P = nE \times i \times k$,

i.e., $$\frac{P}{nEk} = i \qquad . \quad (2)$$

Writing in the value of P from (1) we have :—

$$\frac{EIk}{nEk} = i$$

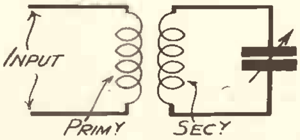


Fig. 3.—SECONDARY WINDING TUNED BY A CONDENSER.

Cancelling the E and the k on the left-hand side we have :—

$$\frac{I}{n} = i \qquad . \quad (3)$$

In other words, when the voltage is amplified, or stepped-up, n times, the current is "de-amplified," or stepped-down, n times. The same reasoning shows that when the current is increased the voltage is decreased. In the case just considered, if the input current be 4·8 amps., the output current will be $\frac{4{\cdot}8}{2{\cdot}4}$ amps., or 2·0 amps.—*i.e.*, the current is stepped down 2·4 times.

Turns Ratio of a Transformer

In the case of transformers of the type illustrated in Fig. 1, where the two coils are very close together, the voltage step-up —*i.e.*, $\frac{e_s}{e_p}$, where e is the voltage and the subscript denotes primary and secondary —is equal to the ratio of the number of turns of wire on the secondary coil to the number of turns on the primary coil.

i.e., $$\frac{e_s}{e_p} = n \qquad . \quad . \quad (4)$$

where n is the TURNS RATIO of the transformer.

Mutual Induction

It is important to note here that both the primary and secondary windings of the transformer possess self-inductance, and a mutual inductance exists between the two coils. When the transformer is connected in a circuit the effect on the transformer is as if an impedance or a pure resistance is connected across its secondary winding (see Fig. 2). Now since the mutual induction effect is *mutual*—*i.e.*, it operates from primary to secondary, and *vice versâ*—the *effect* of the secondary load Z is conveyed into the primary circuit. We cannot give proof of this fact here beyond stressing the mutual aspect of the induction effect. The extent of the

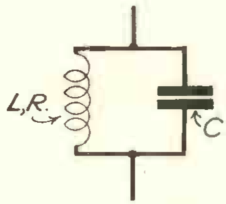


Fig. 4.—A PARALLEL TUNED CIRCUIT.

effect of the secondary load in the primary circuit will be dealt with when specific cases arise.

Secondary Load

In Fig. 2 the secondary load Z may take several forms, such as a valve-filament, in the case of a mains transformer, or the speech coil winding of a moving-coil loud speaker, in the case of an output transformer of a receiver, or it may be due to the fact that the secondary winding is tuned by a condenser (as in Fig. 3) as occurs in the case of transformers used for coupling the various radio frequency and intermediate frequency amplifier stages of a receiver.

Dynamic Resistance

In this last case the secondary impedance is what is known as the DYNAMIC RESISTANCE of the whole tuned circuit. In Sections VI. and VII. we dealt with impedances and tuned circuits, and referred to the magnification factor of a coil in a tuned circuit. It has also been pointed out that a coil has a certain high-frequency resistance, and that the impedance of a *series* circuit at resonance is equal to this high-frequency resistance.

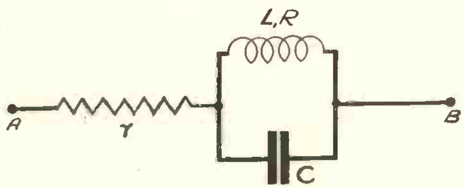


Fig. 5.—CIRCUIT CONNECTED IN SERIES WITH ANOTHER RESISTANCE.

Impedance at Resonance of a Parallel Circuit

In the case of the *parallel* circuit the impedance at resonance is a maximum and its actual value is the dynamic resistance of the circuit. Consider the parallel tuned circuit of Fig. 4. Its impedance at resonance is :—

$$Z = \frac{1}{RC\omega}\sqrt{L^2\omega^2 + R^2} \quad . \quad . \quad (5)$$

In the square root expression R is very small compared with $L\omega$ (certainly less than one-fifth of $L\omega$), so that it can be neglected, hence :—

$$Z = \frac{1}{RC\omega}\sqrt{L^2\omega^2}$$

i.e., $$Z = \frac{L\omega}{RC\omega}$$

or $$Z = \frac{L}{RC}$$

This is the dynamic resistance and will be denoted by R_d, thus :—

$$R_d = \frac{L}{RC} \quad . \quad . \quad . \quad (6)$$

R_d is in ohms when L is in henries, C in farads, and R in ohms ; R_d is also in ohms when L and C are in microhenries and microfarads, respectively. The dynamic resistance of a parallel circuit comprising an inductance of 300 mH., of resistance 3 ohms, and a capacity of ·00025 mfd., is :—

$$R_d = 3 \times \frac{300}{\cdot 00025} \text{ ohms.}$$

i.e., $$R_d = \frac{100}{\cdot 00025} \text{ ohms.}$$

or $R_d = 400{,}000$ ohms.

Calculation of Total Resistance

This dynamic resistance behaves in the same way as a pure resistance, and hence, if the circuit is connected in series with another resistance, as in Fig. 5, and a source of signals connected to the terminals A and B, the total impedance of the circuit, *when L and C are tuned to resonate with the signal frequency*, is merely the sum of the dynamic resistance of the tuned circuit and the pure resistance,

i.e., total resistance $= r + R_d$

or total resistance $= r + \frac{L}{RC} \quad . \quad . \quad (7)$

Vector and Actual Impedance

When resonance does not occur (*i.e.*, $L\omega$ not equal to $\frac{1}{C\omega}$) the total effective resistance (the impedance) of the circuit of Fig. 5 can only be obtained by finding (1) the total pure resistance, and (2) the total reactance. These two are then added by the vector method, already described in sections VI. and VII., viz. :—

Vector impedance (z) = total pure resistance (R_p) + j × total reactance (X).

i.e., $z = R_p + jX$ . . . . (8)

and the *actual* impedance is then :—

$$Z = \sqrt{R^2_p + X^2} \quad . \quad . \quad . \quad (9)$$

We shall refer to these equations again when we deal with the action of the valve.

Types of Transformers and Chokes

There are two main types of transformers and chokes used in radio work :—

(1) Those used for circuits in which the frequency of the current is fixed (*e.g.*, mains transformers and smoothing chokes).

(2) Those used in circuits where several different frequency currents are passing.

Of the latter type there are two important sub-divisions: (*a*) those used in circuits in which one current of one frequency passes at a time—*i.e.*, radio frequency transformers and chokes dealing with one radio frequency at a time, and (*b*) those used in circuits which carry currents of several frequencies simultaneously—*i.e.*, AUDIO (or audible) frequency transformers and chokes dealing with the range of audible frequencies transmitted from the studio. We shall deal at greater length with these types later, and we shall restrict our attention for the present to considering some of the features of audio-frequency transformers.

Features of Audio-frequency Transformers

The relation (4) is only approximate in the case of audio-frequency transformers, and a variety of other factors have to be taken into consideration. One of the chief of these is the effect of the iron core on which the transformer is assembled. Other important factors are the capacity between the two windings and the manner in which the primary and secondary coils are wound—*i.e.*, whether wound in one or more sections, and whether placed next to each other or on top of each other, and so on.

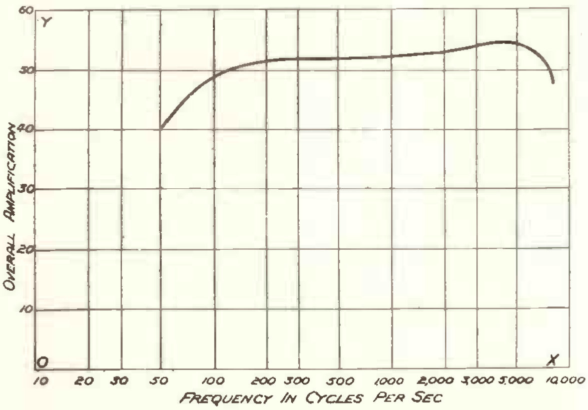


Fig. 6.—CURVE SHOWING TOTAL AMPLIFICATION OBTAINED FROM THE COMPLETE UNIT COMPRISING VALVE AND TRANSFORMER.

Frequency Distortion

The well designed transformer gives approximately constant amplification at all frequencies. This is necessary in order that certain notes shall not be emphasised relative to others, resulting in distortion of the music—not necessarily distortion which is disagreeable to the ear, but nevertheless, distortion in as far as the original balance between the notes in the studio is not being preserved. The emphasising or attenuating of a note of one frequency relative to a note of another frequency is known as FREQUENCY DISTORTION. Thus in the case of, say, a 1 : 5 voltage step-up transformer, the ideal is that every signal voltage, whatever its frequency, shall be amplified 5 times. Frequency distortion is present if voltages of one frequency are amplified 5 times, and voltages of other frequencies amplified more or less than 5 times.

Amplitude Distortion

Another form of distortion which can occur in audio-frequency transformers is the distortion of notes of the same frequency. The term AMPLITUDE DISTORTION is used to describe this form of distortion. Suppose a note of a certain frequency is represented in the transformer circuit by an alternating current signal of maximum amplitude of, say, 5 volts. If the performer in the studio now produces a note of twice the amplitude, the transformer should now be handling a signal of amplitude 2 × 5 volts, or 10 volts. If the new signal amplitude is not twice the original value, but some other value, then distortion has occurred. (Both of these forms of distortion may occur in parts of a receiver other than the audio-frequency transformers.)

How the Performance of an Audio-frequency Transformer is shown

The actual amplification obtained with a particular transformer depends very largely on the type of valve with which it is used. In view of this it is usual to express the record of the performance of an audio-frequency transformer in the form of a curve showing the total amplification obtained from the complete unit comprising valve and transformer. We shall refer to this again. Such a curve is reproduced in Fig. 6, and it will be seen that the frequency scale is not equispaced but is a logarithmic scale. This enables the whole range of audible frequencies from about 20 cycles per second to 10,000 cycles per second to be covered on a reasonably small size of graph paper.

The graph was obtained by measuring the output voltage at different frequencies. The input voltage, at all frequencies, was maintained the same.

The fact that the curve is not a straight line parallel to the OX axis shows that notes of the same initial amplitude but of different frequency have different amplitudes when they have passed from input to output circuits. That is to say, frequency distortion has occurred. The extent of the *effect* of frequency distortion shown by the curve depends on the sensitivity of the ear to changes in intensity of musical notes.

The response of the ear to sounds is an important factor governing the accuracy of the reproduction required from a radio receiver or radio gramophone, and we must refer to the matter briefly.

How the Sensitivity of the Human Ear varies

The ear behaves in a manner which is characteristic of the behaviour of all the senses. It is not sensitive to a fixed definite change in intensity of sound. Instead, it is sensitive to a fixed *percentage change* in intensity. Thus a change in intensity from 20 to 21 units of sound intensity represents a change of 1 unit, or a percentage change of 5 per cent. This is not sufficient to be perceived by the ear. A change from 2 to 3 units is also a 1-unit change, but the percentage change is 50 per cent., a change which is easily detected. The sensitivity of the ear varies widely from person to person, and it would be quite wrong to speak of an *average ear*, but as a rule it is generally accepted that the ear can scarcely perceive a 20 per cent. intensity change, and can appreciate a 25 per cent. change. The variation shown by the curve of Fig. 6 is, of course, an amplification variation, and does not indicate, directly, intensity variations.

Two Ways of Expressing Electrical Power

When we discuss the ear's response to sounds we are referring to its response to actual sound waves. These waves come from the loud speaker and are due to the electrical signals in the receiver. The intensity of a sound wave is its power and, this corresponds exactly to the electrical power in the receiver circuits. Thus, the figures just given for the ear's sensitivity are true for electrical power in the receiver as well as for sound intensity, provided that the loud speaker does not introduce amplitude distortion. We have already seen that the power in an electrical circuit can be expressed in terms of the current and voltage of the circuit. There are two other ways of expressing electrical power which are often used in power calculations. For the two cases of a D.C. circuit, and of an A.C. circuit comprising pure resistance only—*i.e.*, $k = 1$—it can be shown that:—

$$P = EI \text{ as before in equation} \qquad (1)$$

also $$P = \frac{E^2}{R} \qquad (10)$$

and $$P = I^2 R \qquad (11)$$

where R is the resistance of the circuit in ohms. As before, P is in watts, I in amps, and E in volts. These three formulæ are identical and it is usual to use the one which is most convenient in practice.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

COMPLETE WIRELESS

A PRACTICAL AND AUTHORITATIVE WORK FOR EVERYONE INTERESTED IN THE WIRELESS INDUSTRY

General Editor :

EDWARD MOLLOY

Advisory Editor :

RALPH STRANGER

VOL. III

Contributors to Vol. III :

F. W. LANCHESTER, LL.D., F.R.S.
FRANK PRESTON
L. D. MACGREGOR
H. E. J. BUTLER
G. S. HOLIDAY
EDWARD W. HOBBS, A.I.N.A.
RALPH STRANGER
W. F. FLOYD, B.Sc. (Lond.)
J. H. A. WHITEHOUSE
H. J. BARTON CHAPPLE, A.M.I.E.E.
W. GEORGE
L. G. WARNER

GEORGE NEWNES LIMITED
SOUTHAMPTON STREET, LONDON, W.C.2

ii

Index and Classified Key enabling all articles on any particular subject to be readily turned up will be found at the end of the Complete Work.

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD., LONDON AND TONBRIDGE.

PREFACE TO VOL. III

THE first article in this volume is one that should be read carefully by every reader of this work. It deals with the theory of the thermionic valve, and is a very clear exposition of this important subject, which should be thoroughly digested by everyone in the radio industry who wishes to understand what happens inside the valve. This article is one of several in this volume which deal with the subject of valves, others of special interest being those dealing with the mathematics of the valve and the use of variable-mu valves.

Another feature of special interest is the section on "Valve Coupling Systems," which shows diagrammatically practically every conceivable method of coupling between valves, and which will be found invaluable for reference purposes. The subject of coupling systems is also dealt at some length in the article on "Receiver Design."

Special attention has also been paid in this volume to Electric Gramophone Motors and Gramophone Pick-ups, including a thorough treatment of the Automatic Record Changer.

Further additions to the series of Servicing articles include the following :—

Ultra
Philco
His Master's Voice
Marconiphone
Majestic
Baird Televisor

The latter is of interest in view of the B.B.C. broadcasts. The general subject of television, including all modern systems, will be dealt with later. Important developments in this subject are expected in the near future, and the subject is one with which everyone interested in the radio industry should be acquainted.

An article of special interest to wireless dealers is that on "Battery Charging Methods," while special mention may also be made of "Dual Balanced Loud Speakers and Amplifiers," and "Making a Start in Amateur Transmission." Although the latter will only be of direct use to a limited number of readers, it is a phase of wireless which should not be lost sight of. The work of the serious amateur has been of great importance in the rapid development and improvement of wireless receiving sets.

E. M.

CONTENTS

CONSTRUCTION • EXPERIMENTAL • THEORY

NEWNES COMPLETE WIRELESS

In This Part

VALVE THEORY MADE PLAIN

VALVE COUPLING SYSTEMS

POTENTIOMETERS

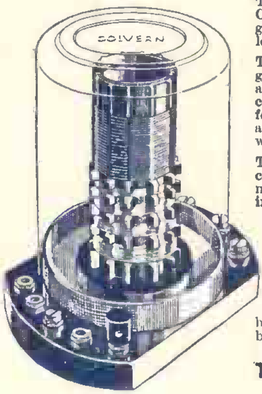
SERVICING ULTRA RECEIVERS

1/-

Part 17

IN ABOUT 24 WEEKLY PARTS

COLVERN
T.D. COIL
AN UP-TO-DATE COIL WITH UP-TO-DATE FEATURES



TYPE T.D., an entirely new COLVERN COIL, designed to give super selectivity on both long and broadcast wave-bands.

The coil is completely screened, giving a very neat appearance, and incorporates tapped aerial coupling and reaction, while the four alternative aerial tappings are arranged as sockets with a wander plug.

The first two tappings give aerial couplings similar to those normally employed but with greatly increased selectivity.

Nos. 4 and 5 give a high degree of selectivity with weak aerial coupling—suitable for use in a "swamp" area.

A most important feature of this coil is that there is no break through on the long waveband from B.B.C. stations.

TYPE T.D. - Price 8/6

Our 1933 Booklet Radio List No. 10 is now available and free on request.

COLVERN LIMITED
MAWNEYS RD. · · · ROMFORD, ESSEX

All leading set designers specify
Exide
AND
Drydex
BATTERIES

There is a type for every set.

GRIP
New "BOWSPRING" Wander plug

The "BOWSPRING" gives strong pressure over a far wider range of diameters than any plug we have so far tested.

1½D.

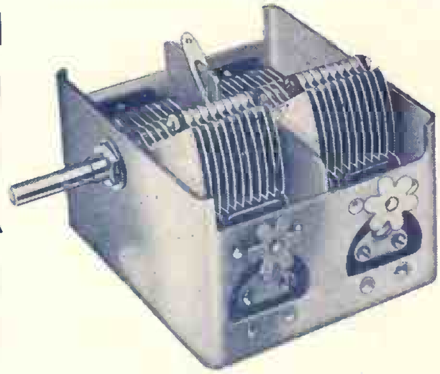
Strong spring and wide self-adjustment. Side entry with Belling-Lee patent grip for flex. 12 indications and 6 plain colours.

BELLING-LEE

Write for list of radio connections.

Advert. of Belling & Lee Ltd., Cambridge Arterial Road, Enfield, Mdx.

NUGANG



Rigid one-piece chassis—very robust construction. *Accurately matched to within ½ m.mfd. plus ½ per cent.* Trimmer to each stage. Supplied semi-screened as illustrated or fully screened with lid. Capacity ·0005.

SEMI-SCREENED		FULLY SCREENED	
2-gang	14/-	2-gang	16/-
3-gang	21/-	3-gang	23/6
4-gang	28/-	4-gang	31/-

PRECISION INSTRUMENTS

Advertisement of Jackson Bros. (London), Ltd., 72 St. Thomas' St., London, S.E.1. Telephone: Hop. 1837.

PART 17.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XIII—VALVES

IN our survey of the theory of wireless we are now approaching the high-frequency amplifying circuit, the detector circuit and the low-frequency amplifying circuit.

It is impossible to understand clearly the principles underlying both detection and amplification unless the cycle of events taking place inside a thermionic valve is well understood.

In mechanics a valve is a device which possesses unidirectional conductivity, in other words, it will allow a fluid or a gas to pass in one direction only. In electrical work we are dealing with neither fluids nor gases, but with electrons. The electrical valve is therefore a device which possesses a unidirectional conductivity of electrical current or electrons.

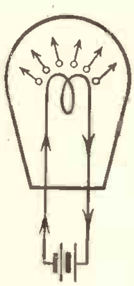


Fig. 1.—Showing Electrons Ejected by the Surface Atoms of the Filament.

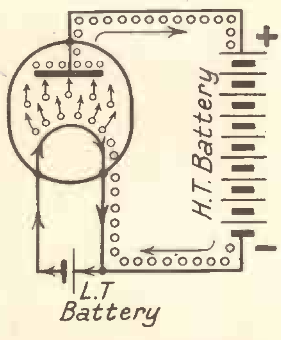


Fig. 2.—This shows the Metal Filament and Metal Plate, isolated from each other, Sealed in an Evacuated Glass Bulb.

Note the direction of the flow of electrons.

Why a Thermionic Valve is so-called

It is called a thermionic valve because, in its work, it utilises thermal or heat energy which is communicated to electrons resident in one of the conductors inside the valve.

Sir Ambrose Fleming was the first to observe in 1883 a peculiar effect of the carbon filament electric lamp that in some cases particles of carbon were shot off the incandescent filament in straight lines and deposited on the walls of the glass bulb. These particles formed a sort of a shadow of the filament on the glass and thus drew his attention to this remarkable phenomenon. It was not until 1899 that it was shown that these particles were atoms of electricity now called electrons by J. J. Thomson (Fig. 1).

It has also been found that the emission of electrons from the surface atoms of such a filament was dependent on and increased with the temperature of the filament. Apparently what is happening is that as the temperature of the filament is increasing, and, therefore, the rate of molecular vibration becomes greater, the great agitation of molecules and atoms composing the filament produces frequent collisions between the atoms and the result is that electrons are being "fired" into space with considerable energy.

Sir Ambrose Fleming was the first to make use in 1904 of an electric lamp with a metal cylinder round the filament which, in its state of incandes-

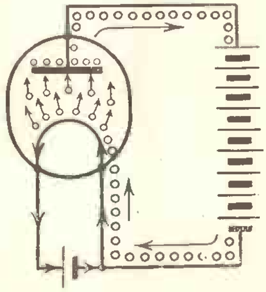


Fig. 3.—Showing how action of the Valve is not affected by the way in which the L.T. Battery is connected.

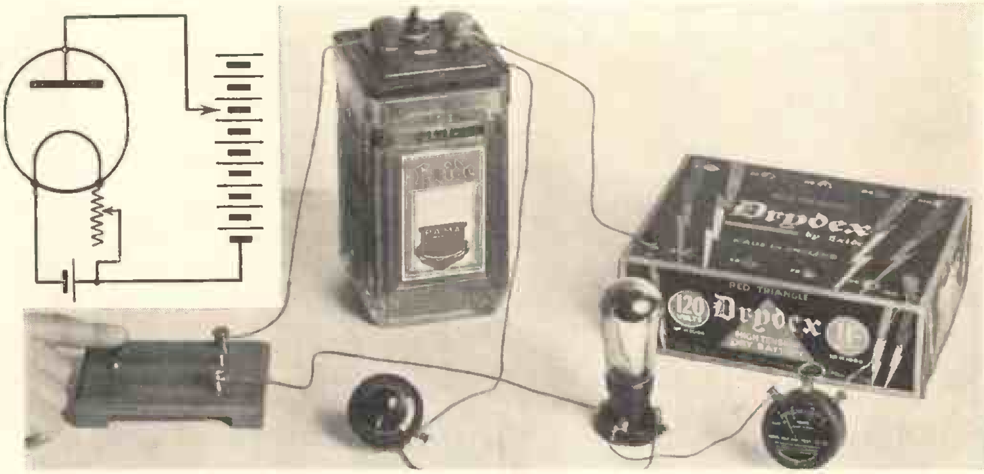


Fig. 4.—EXPERIMENT SHOWING HOW ANODE CURRENT VARIES WITH FILAMENT CURRENT. Here the filament current is only just on, and the anode current is 2 m.a. Fig. 4A (inset) shows the connections diagrammatically.

Fig. 5.—EXPERIMENT SHOWING HOW ANODE CURRENT VARIES WITH FILAMENT CURRENT. Here the resistance has been turned half on, and the anode current is now 13 m.a.

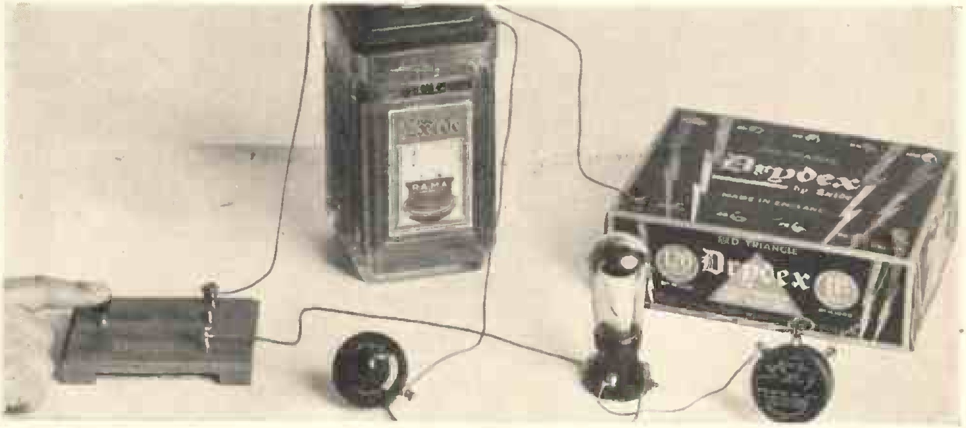


Fig. 6.—EXPERIMENT SHOWING HOW ANODE CURRENT VARIES WITH FILAMENT CURRENT. The filament current is at full strength, and the anode current is 30 m.a.

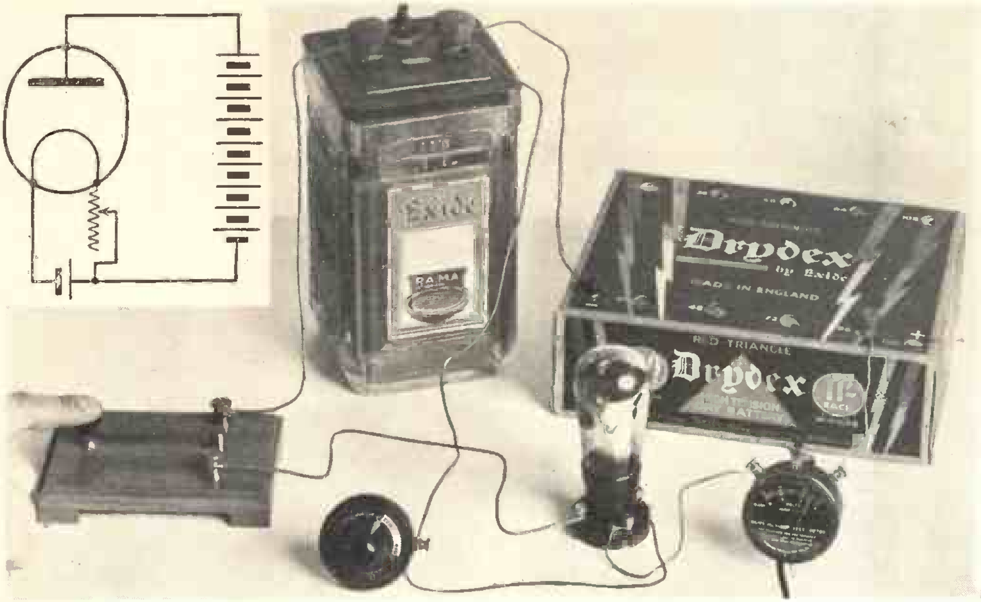


Fig. 7.—Effect of varying the High-tension Voltage.

Here we see the high-tension voltage lowered to 96 volts. The anode current is now 24 m.a. Compare with Fig. 4, which shows the anode current when H.T. voltage is 120 volts. Fig. 7A (inset) shows the connections diagrammatically.

Fig. 8.—Effect of varying the High-tension Voltage.

The high-tension voltage is now 72. The anode current has been reduced to 14 m.a.

cence, will fire off electrons, and thus act as a rectifier for high-frequency electric oscillations.

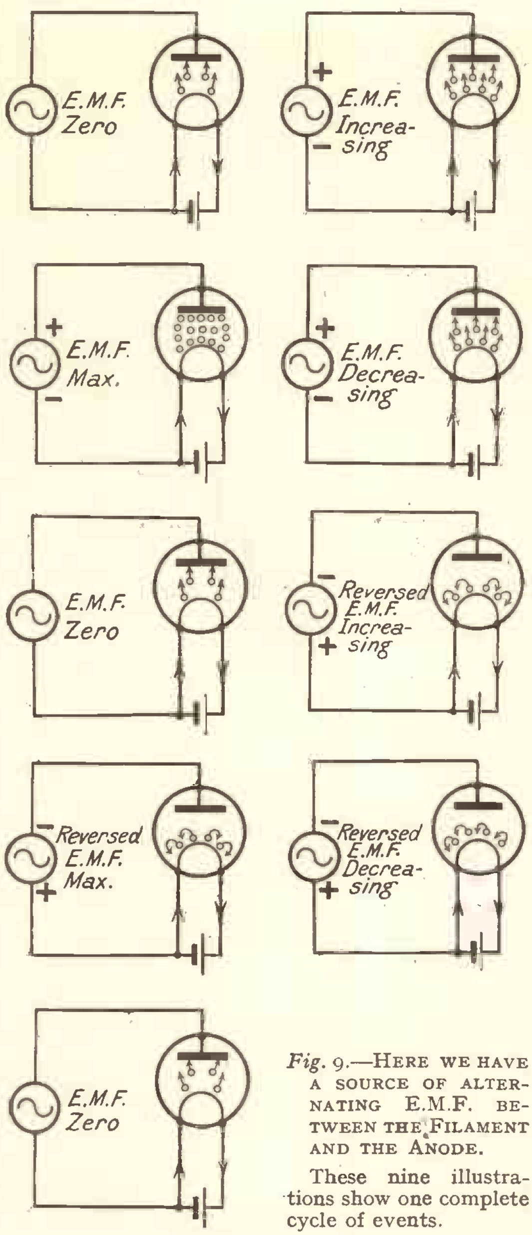


Fig. 9.—Here we have a source of alternating E.M.F. between the Filament and the Anode.

These nine illustrations show one complete cycle of events.

Evacuated Glass Bulb

This lead to an arrangement shown in Fig. 2, which consists of an evacuated glass bulb inside which, isolated from each other, are sealed a metal filament and a metal plate. The latter is made poor in electrons, and, therefore, predominant in protons with the help of the positive terminal of a large battery. The filament is heated by passing a current through it from a separate supply, in this case a cell.

What the Cell does

The function of the cell is merely to send a current through the filament and bring it up to a certain temperature. As soon as this temperature is high enough an electron emission from the surface atoms of the filament will take place and these electrons being attracted by the unbalanced protons on the plate or *anode*, as it is called, will " land " on the anode and while accumulating there will be made to drift towards the positive terminal of the large battery by their mutual repulsion. On arriving at the positive terminal of the battery they will be dealt with by the latter, and, with the help of various chemical processes taking place there, will be transferred to the negative terminal of the same battery. There again mutual repulsion will intervene and electrons will drift towards the filament.

Why the Filament does not melt

There are many amateurs who are exceedingly puzzled to know why " the current flowing from the large battery " to the filament does not overload the latter and melt it." This point has never been explained in any text-book. In the first place the current flowing through the filament from the small battery or *low-tension battery*, as it is called, to distinguish it from the large battery which is usually referred to as the *high-tension battery*, is flowing *inside* the filament, *i.e.*, the electrons from the low-tension battery are migrating from atom to atom inside the filament.

In the second place, the electrons ejected from the filament come from the surface atoms which are thus impoverished and are made predominant in protons. The unbalanced protons in the surface atoms, if they try to compensate themselves at the expense of the inner atoms of the filament, have to do so against the attractive force of the unbalanced protons of the positive side of the low-tension battery.

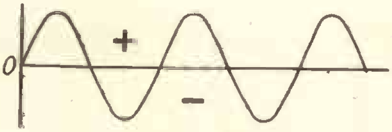


Fig. 10.—CURRENT CURVE IN THE CASE OF AN ORDINARY CIRCUIT.

This shows an alternating E.M.F. with its positive half-cycle above the base line and its negative half-cycle below the base line.

On the other hand, they have the accumulated store of electrons repelling each other, arriving from the negative terminal of the high-tension battery, at the foot of the filament. It is clear that the unbalanced protons in the surface atoms of the filament will compensate themselves at the expense of the H.T. battery and thus replenish their store continuously all the time electrons are being ejected from the filament. Again, it should be realised that the number of electrons passing through the inner atoms of the filament and the number of electrons creeping along the surface atoms of the filament on their arrival from the negative terminal of the H.T. battery is different. While inside the filament we have a current flowing of the order of a tenth of an ampere, the current passing in the anode circuit (from anode of the valve, *viâ* H.T. battery and along the lead to the filament) is only of the order of a few thousandths of an ampere (a few milliamperes).

Flow always in One Direction

If you compare Figs. 2 and 3 you will see that the action of the valve is not affected by the way in which the L.T. battery is connected. While the connections are made, a steady flow of electrons will take place from the hot filament to the anode and from thence round the anode circuit back to the surface of the filament.

You will notice that *the flow is always in one direction, from the filament to the anode.*

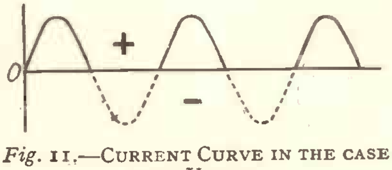


Fig. 11.—CURRENT CURVE IN THE CASE OF A VALVE.

It will be seen that the valve allows the alternating current to pass in one direction only.

Varying the Strength of Current flowing through the Filament

Let us see what will happen when we start to vary the conditions governing the flow of electrons from the filament to the anode. If we start with a given positive potential on the anode, *i.e.*, with a given voltage of a H.T. battery connected to the anode, we can vary the number of electrons leaving the surface of the filament and arriving at the anode by varying the temperature of the filament, *i.e.*, the strength of current flowing through the filament. How can we vary the strength of the current flowing through the filament? Why, by varying the resistance of the latter. Thus, the first control of the flow of electrons through a valve can be carried out by means of a variable resistance in series with the filament and the L.T. battery as shown in Fig. 4A.

Another Method of Control

We can have another control by varying the attractive force of the anode. This can be done by using an ordinary H.T. battery with a number of sockets and a wander plug, as shown diagrammatically in Fig. 7A. The lower the voltage of the H.T. battery the lower the attractive force of the anode, and, therefore, the fewer electrons there are being attracted from the surface of the filament.

Thus, we can control the flow of electrons from the filament to the anode by either varying the current flowing through the filament or by varying the voltage on the anode.

Two Electrode Valve

The valve illustrated in Figs. 2, 3, 4A and 7A has two elements or two *electrodes*, as they are usually referred to, the filament and the anode, and for this reason this type of valve is called a *two electrode valve*, or a *diode*.

In the case of a two-electrode valve the electrons leave the filament

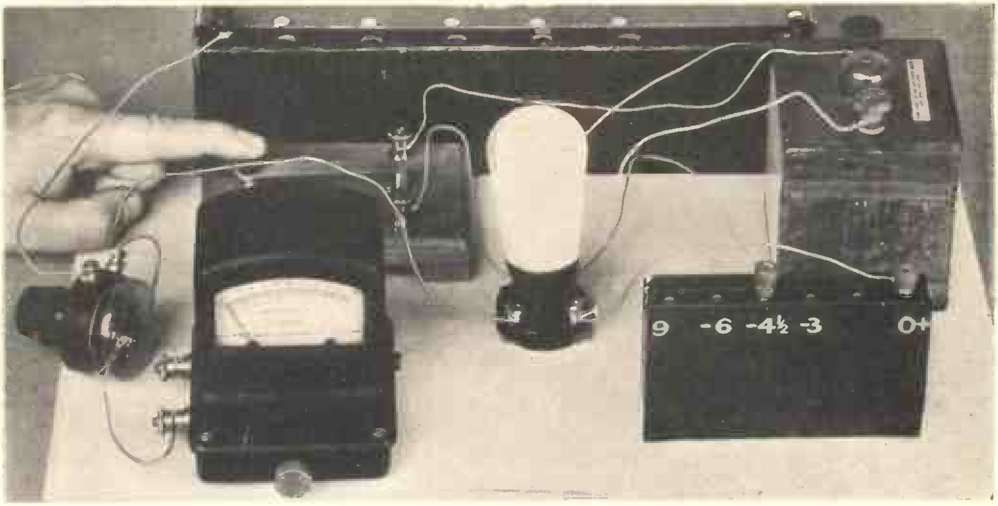


Fig. 12.—ANODE BEND DETECTION.

Note that with the grid bias at the value $-4\frac{1}{2}$ volts, there is practically no current flowing in the plate or anode circuit. The needle of the " microid " instrument is at zero.

in considerable numbers, and since they repel each other there will be a mutual interference with each other's progress towards the anode and some of the electrons will never reach their goal and will fall back upon the filament. This interference is spoken of as a negative charge in space between the filament and the anode, or simply as *space charge*. As you will see later, this has been eliminated to a large extent in modern valves.

What happens when a Source of Alternating E.M.F. is connected between Filament and Anode

Let us see what will happen if we connect a source of an alternating E.M.F. between the filament and the anode.

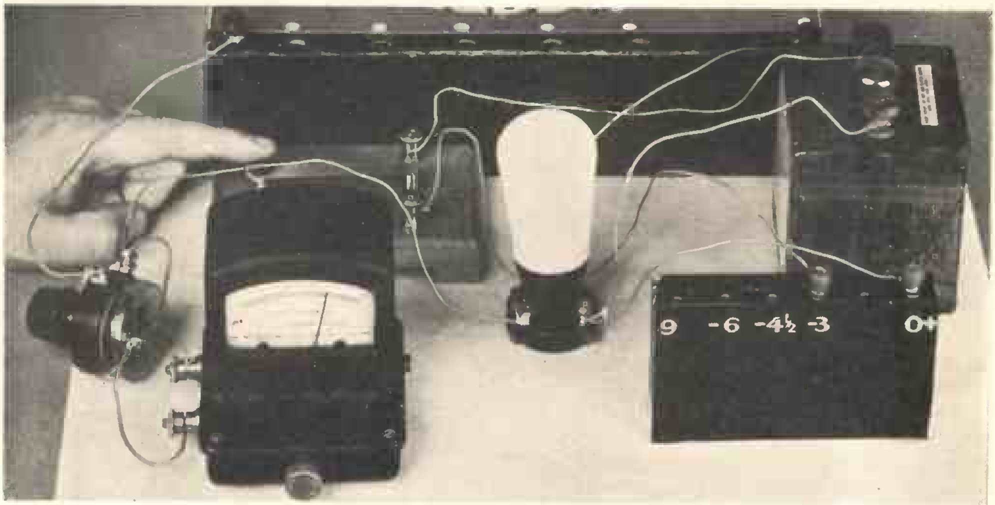


Fig. 13.—ANODE BEND DETECTION.

Here we see the effect of raising the grid voltage by $1\frac{1}{2}$ volts. An appreciable current is now flowing in the anode circuit as can be seen by the instrument needle.

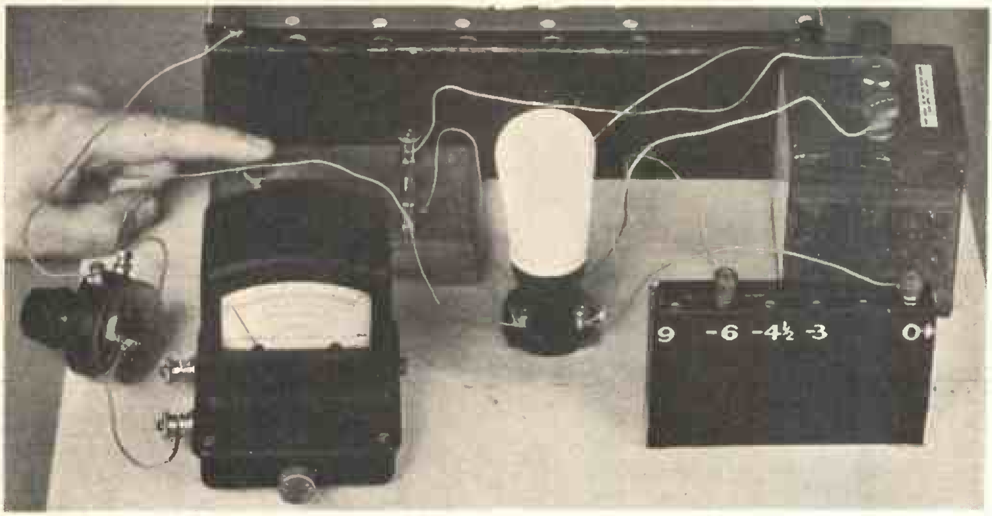


Fig. 14.—ANODE BEND DETECTION.

The grid bias voltage has now been *decreased* 1½ volts to −6 volts. It can be seen that this produces little effect on the anode current. Thus if the grid is biassed at −4½ volts, only the positive halves of the incoming signal waves affect the anode current. This is anode bend rectification.

In Fig. 9 we have such an arrangement. This shows that as the alternating E.M.F. is passing from zero to a gradually increasing positive potential, reaching its maximum, and then gradually but quickly falling to zero again, only to reverse its direction and start increasing the negative potential to a maximum and then falling to zero once more through one complete cycle of events, the anode, during the first half-cycle, will acquire a gradually increasing positive potential which will reach a maximum and then diminish to zero, and during the second half-cycle do the same, but this time with the negative potential.

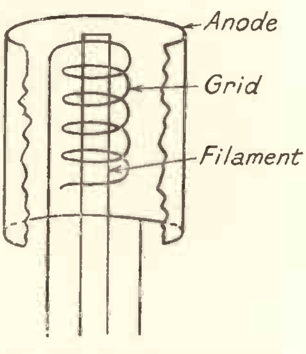


Fig. 15.—THE BASIC METHOD OF SUSPENDING THE THREE ELECTRODES.

When E.M.F. is reversed

Since we already know that if electrons are to flow from the filament to the anode the latter must have a positive potential, as the positive half-cycle of the alternating E.M.F. progresses electrons will flow from the filament to the anode in increasing numbers till the maximum is reached. Then as the positive potential of the anode is declining the electron flow will diminish till it will become zero. When the E.M.F. is reversed and the anode is made negative, no electrons will flow from the filament to the anode throughout the half-cycle. This is clearly shown in Fig. 9.

The Second Half-cycle

During the second half-cycle, while the anode is negative the electrons leaving the filament will be simply repelled and will fall back upon the filament. What does this mean? Since during the second half-cycle no electrons are flowing between the fila-

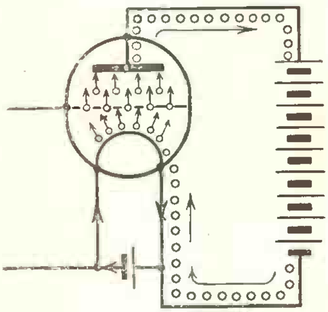


Fig. 16. — DIAGRAMMATIC ARRANGEMENT OF VALVE SHOWING THREE ELECTRODES.

Note that the electrons passing from the filament to the anode have to pass the grid.

ment and the anode the alternating E.M.F. remains inactive for a whole half-cycle as far as the valve is concerned. A current will flow only during the positive half-cycle.

What the Valve actually does.

If we show an alternating E.M.F. with its positive half-cycle above the base line and its negative half-cycle below the base line, as in Fig. 10, then if the E.M.F. were active all the time as is the case in an ordinary circuit, in which a valve is not included, the current curve would be of exactly the same character and would appear as that shown in Fig. 10. But, in the case of the valve, since the current is flowing only during the positive half-cycle, the curve of current will assume the character of that shown in Fig. 11. You see what the valve does? It makes an alternating current pass in one direction only, in a series of jerks mixed with equal inactive intervals. Such a current is called a *rectified* alternating current, and since it is of pulsating character it is also called a *pulsating* current. In effect, it is equivalent to a direct current. Here, then, we have the means of converting an alternating current into a direct current. As you will see later, this is the method used for mains receivers to supply them with direct current from an alternating supply.

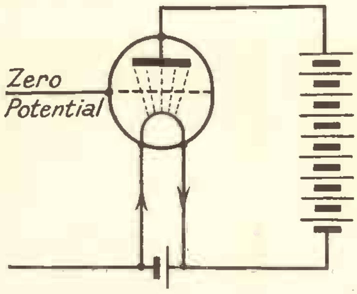


Fig. 17.—This shows the Flow of Electrons with the Grid at Zero Potential.

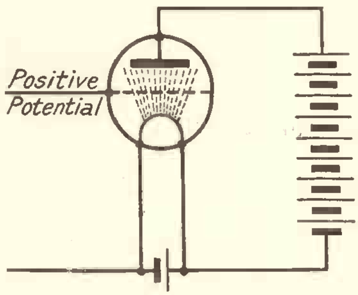


Fig. 18.—This shows the effect of making the Grid positively Charged.

The anode is helped to attract electrons.

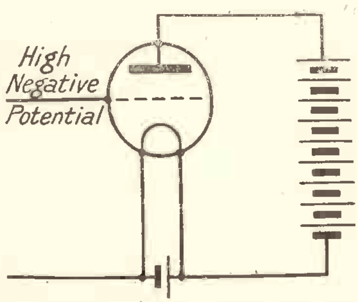


Fig. 19.—Effect of applying a High Negative Potential to the Grid.

The flow of electrons is stopped altogether.

Why Crystal and Valve are both called Rectifiers

A crystal which has a very small resistance to a current flowing in one direction and a very large resistance to a current flowing in the opposite direction behaves in the same way in the presence of an alternating E.M.F., and for this reason both the crystal and the valve are called *rectifiers* (of alternating currents).

It should be remembered that it is the valve that made "wireless" what it is to-day. If not for the valve we should not have had broadcasting. Therefore, one cannot devote too much time to study of valves, and, for this reason, I have to ask my readers to read very carefully this particular article and any other article dealing with valves in this work.

Addition of a Third Electrode

The question of control of the flow of electrons through the valve is a highly important one, and researches in this direction lead to the addition of a third electrode to the Fleming valve, thus converting it from a diode into a *triode*.

It should be clearly understood that the real inventor of the valve is Sir Ambrose Fleming, who utilised the Edison effect with such brilliant results. The additions that have been made to his valve are merely improvements of the original idea.

The Grid

Dr. Lee de Forest, an American, introduced between the filament and the anode a third electrode, which he called the *grid*. In practice the filament is surrounded by a spiral wire which constitutes the grid, and the grid is, in its turn, surrounded by a metal cylinder forming the anode. The shape and the method of suspension of the three electrodes varies a good deal, but the basic method can be illustrated as shown in Fig. 15. This can be shown diagrammatically as in Fig. 16. From Fig. 16 it is clear that electrons passing from the filament to the anode have to pass the grid. The latter being in the form of an open spiral does not impede their flow to a very great extent.

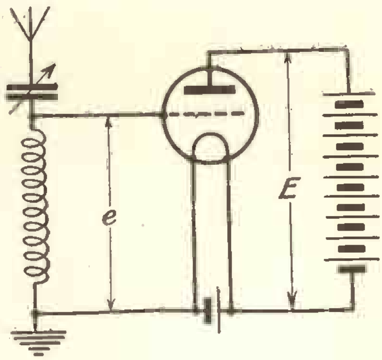


Fig. 20.—Showing how the Valve can Act as an Amplifier by converting small fluctuations of Voltage across the Grid and the Filament into large Voltage Fluctuations across the Anode and Filament.

How the Grid helps the Anode to attract Electrons

Now, if we make the grid positively charged by communicating to it a positive potential (Fig. 18) it will help the anode to attract electrons. It will introduce, owing to the presence on its surface of unbalanced protons, an additional attractive force which will accelerate the escape of electrons from the surface atoms of the filament.

Grid Current

In helping the anode, it is bound to help itself, and a number of electrons, instead of proceeding to the anode, will "land" on the grid, and, accumulating there, during the working of the valve, will repel each other and will drift along the grid circuit outside the valve. This is known as the *grid current*, and, as you will see later, this current is made to do work in a receiving circuit. On the other hand, if the grid is made negative it will oppose the work of the anode and will reduce the flow of electrons from the filament to the anode. If the grid is made too negative (Fig. 19) it will stop the flow of electrons altogether and the valve will cease to function.

Why the Valve can act as an Amplifier

Now, the beauty of the whole thing is that *a very small* accumulation of electrons on the grid or a very small deficit of electrons on the grid will produce *large changes* in the strength of the flow of electrons from the filament to the anode. This can mean only one thing: the grid with very little energy communicated to it will produce large changes in the flow of electrons through the valve, so that it will act as a relay releasing large amounts of energy with very small fluctuations on itself. It can be likened to a solitary policeman directing hundreds of horsepower of traffic. A slight motion of the hand and a stream of power is released along the road. For this reason the valve can act as an *amplifier* by converting small

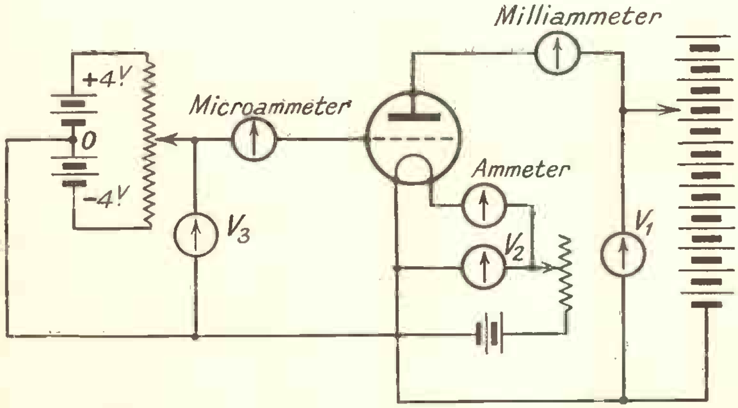


Fig. 21.—Circuit for carrying out Experiments with a Three-electrode Valve.

Fig. 22.—How the Anode Current of a Power Valve is affected by varying the Grid Voltage.

Here the grid voltage is 0, and the anode current 13·5 m.a.

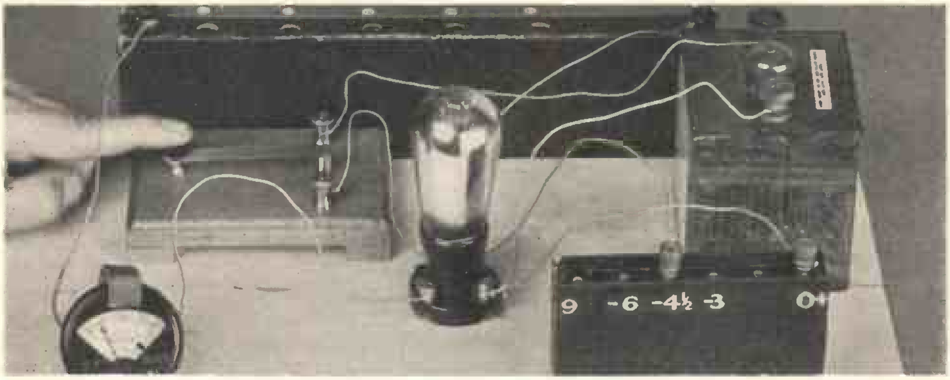


Fig. 23.—How the Anode Current of a Power Valve is affected by varying the Grid Voltage.

When − 4½ volts are applied to the grid the anode current is reduced to 8·5 m.a.

Fig. 24.—How the Anode Current of a Power Valve is affected by varying the Grid Voltage.

Here we see that − 9 volts have been applied and the anode current is reduced to 3 m.a.

Fig. 25.—How the Anode Current of a Power Valve is affected by varying the Grid Voltage.

The grid voltage is now + 4½ volts and the anode current has increased to 22 m.a.

fluctuations of voltage across the grid and the filament into large voltage fluctuations across the anode and the filament, as shown in Fig. 20.

If we connect the grid of the valve to the aerial the grid will receive tiny variations of potential across the tuning circuit, and these will cause large potential variations across the anode and the filament (Fig. 20). The latter potential variations will be added to the voltage of the H.T. battery. The significance of this fact we shall see later, when we are dealing with amplification of wireless signals.

Thus, it is clear that the grid of a valve provides a third and the most important control of the flow of current between the filament and the anode.

Experiment You should try

In order to be able to appreciate fully the behaviour of a three-electrode valve it is necessary to carry out a number of experiments. For this purpose I advise my readers to build the circuit shown in Fig. 21.

Apparatus required

This consists of a valve holder three voltmeters (one to read up to 6 volts for the filament circuit, one to read up to 40 volts for the grid circuit, and one to read up to 200 volts or even higher for the

Fig. 26.—How the Anode Current of a Power Valve is affected by varying the Grid Bias

This shows + 9 volts applied to the grid, resulting in an anode current of 30 m.a.

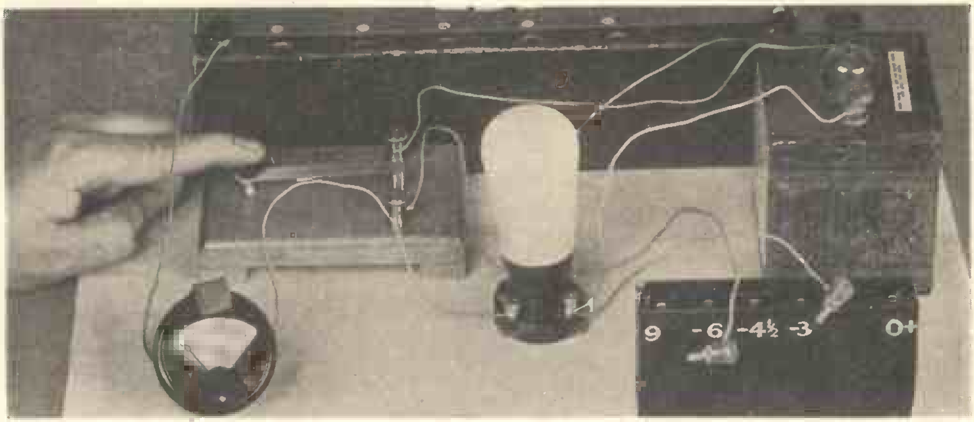


Fig. 27.—How the Anode Current of a Detector Valve is affected by varying the Grid Bias. The grid voltage here is 0, and the anode current 2 m.a.

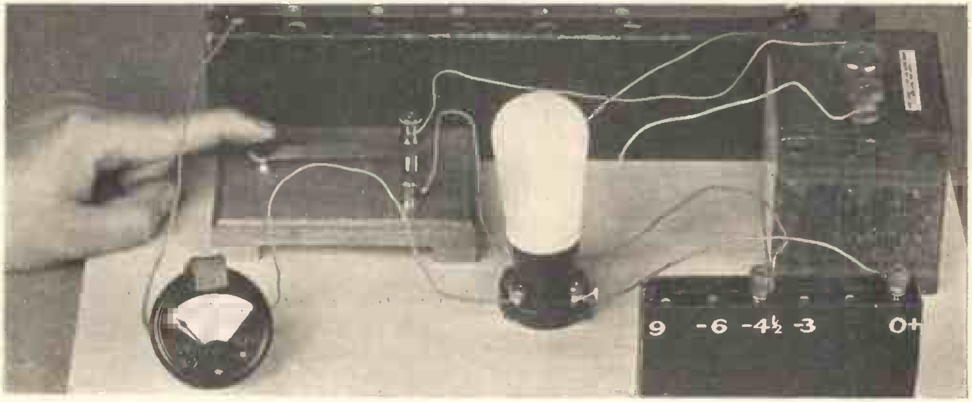


Fig. 28.—How the Anode Current of a Detector Valve is affected by varying the Grid Bias. Here we see that a negative bias of $-4\frac{1}{2}$ volts results in no flow of anode current.

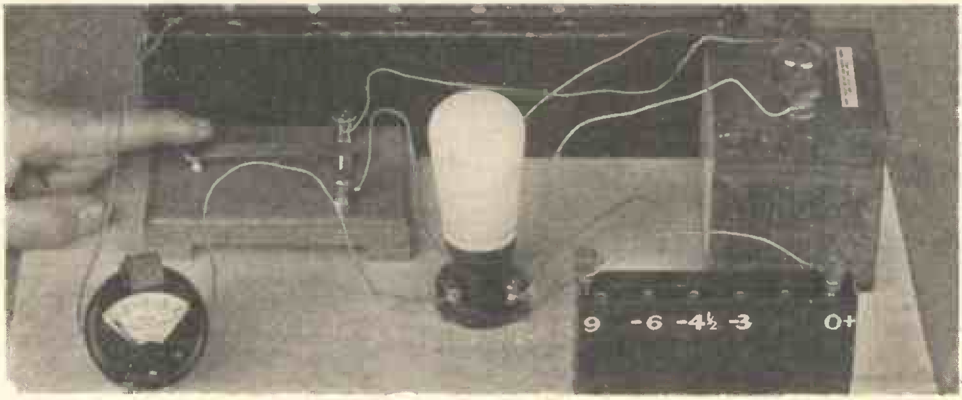


Fig. 29.—How the Anode Current of a Detector Valve is affected by varying the Grid Bias. The grid bias has been increased to -9 volts, and the anode current is still 0.

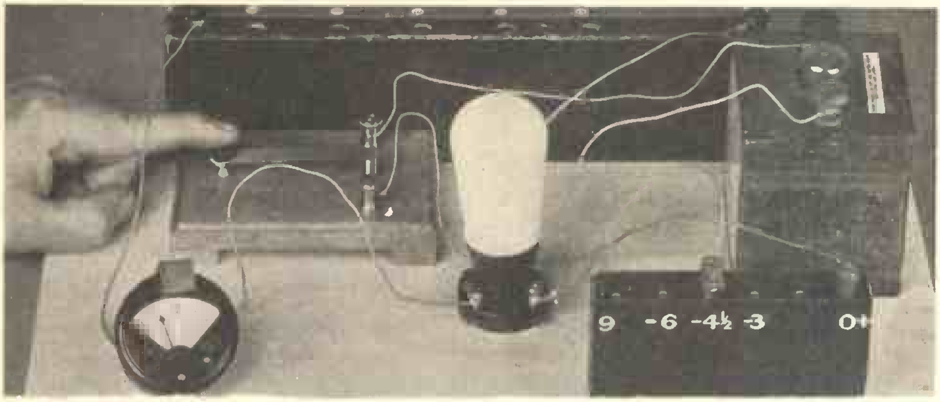


Fig. 30.—How the Anode Current of a Detector Valve is affected by varying the Grid Bias. With + 4½ grid bias, the anode current increases to 11·5 m.a.

anode circuit), one ammeter to read up to 1 ampere in fractions of an ampere, one milliammeter to read up to 100 milliamperes and one microammeter to read up to, say, 20 microamperes. You will also need a potentiometer of, say, 500 ohms, and a filament regulator of 10 ohms.

Connections

The connections are as shown. Now, with the arrangement indicated, the grid potential can be adjusted from plus 4 volts to minus 4 volts. Adjust the potentiometer so that there is no reading on the grid voltmeter, *i.e.*, the grid is at zero potential. Adjust the anode voltage to some definite value, say, 100 volts, and start with the filament regulator in the "out" position, *i.e.*, with no current flowing in the filament. Now, leaving the grid and the anode potentials as they are, start a small current in the filament, note its value on the ammeter and also note the value of the anode current on the milliammeter. Increase the filament current in small steps, each time ascertaining the new value on the ammeter reading and note the corresponding anode current on the milliammeter. In this manner you can jot down opposite each other the corresponding values of anode and filament current with a constant anode voltage and constant grid voltage.

Anode Current increases with Increase of Filament Current

Inspection of these figures will show clearly the fact that the anode current

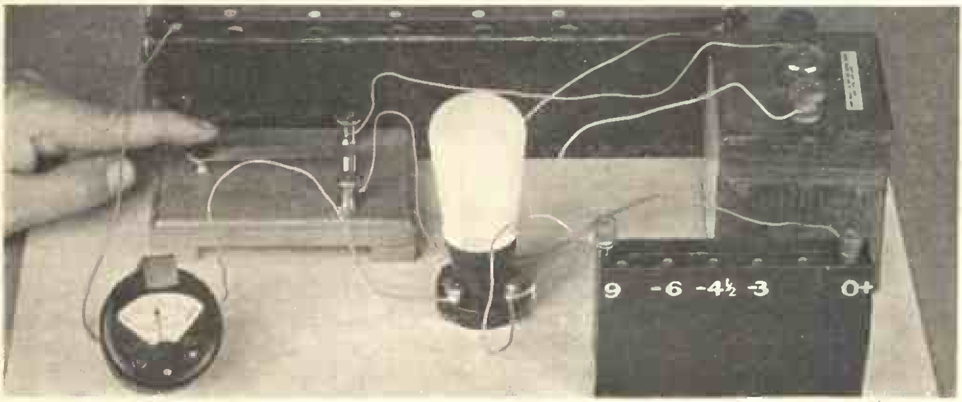


Fig. 31.—How the Anode Current of a Detector Valve is Affected by varying the Grid Voltage.
Here we see + 9 volts applied to the grid resulting in an increase of anode current to 18 m.a.

increases with the increase in the filament current. You should be careful not to increase the filament current beyond the maximum specified by the makers.

Varying the Anode Voltage

Now adjust the filament current to the value specified by the makers of the valve, leave the grid potential at zero, as before, and start varying the anode voltage from zero to its maximum. In this manner you will find that, with a given filament current and grid potential, the anode current will increase as the voltage on the anode is increasing. Jotting down again the values of anode current and the corresponding anode voltage you will see that as the anode voltage increases the anode current increases up to a certain value, when, in spite of further anode voltage increases, the anode current remains stationary.

Saturation Point

You have reached the so-called *saturation point* of electron emission from the filament. The reason for this is that the filament can only emit so many electrons at a time under given conditions. Once this maximum electron emission is reached the filament, whatever the attractive force of the anode, is unable to supply any increased number of electrons.

Varying the Grid Voltage

Having done this, without disturbing the adjustment of filament current, give the anode a voltage of, say, 100 volts, or some other appropriate value, specified by the makers of the valve, and start varying the grid voltage, first from zero to plus 4 volts or more, if you have a larger grid battery (usually called *grid bias* battery), and then back again to zero. After that, vary the grid voltage from zero to minus 4 volts or more. In doing this, and in jotting down the corresponding grid voltages and anode currents, you will discover that as the grid voltage becomes more and more positive again within certain limits the anode current increases, and as the grid voltage becomes more and more negative the anode current decreases, at first, and then stops altogether, if the negative grid voltage is high enough.

Factors which govern Anode Current

Thus, you will discover that the anode current, *i.e.*, the number of electrons flowing from the filament to the anode, depends on (1) the filament current (temperature of the filament) (2) the anode voltage, and (3) the grid voltage.

Interelectrode Capacity

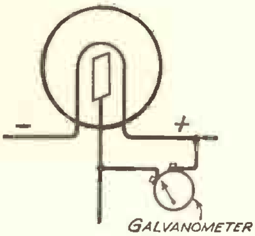
It should be noted that in the case of a circuit shown in Fig. 20 the grid and the filament being two conductors placed apart and insulated from each other, form two plates of a condenser and provide for this reason a certain capacity in the circuit. This combination is thus liable to get charged up like any ordinary condenser, and also to discharge at given intervals. It is clear that such a behaviour on the part of these two electrodes is bound to interfere to some extent with the action of the circuit. This is what we call *interelectrode capacity*. This interelectrode capacity must be taken into consideration when designing a receiver.

Once we are perfectly certain in regard to the action of the three-electrode valve, the screened grid valve and its " variable-mu " variety, as well as the pentode valve, we can proceed with the investigation of the detector and the amplifying parts of the receiving circuit.

THE INVENTION OF THE THERMIONIC VALVE AS A DETECTOR, BY SIR AMBROSE FLEMING, F.R.S.

IN view of the importance of the valve in wireless transmission and reception, readers will be interested in the following authoritative statement of the events which led up to its discovery and application as a detector. The facts are as follows:—

In 1883 Edison constructed a horseshoe-shaped carbon filament of carbonised bamboo and fixed it in an exhausted glass bulb, with a metal plate carried on a wire sealed through the bulb between the legs. He incandesced the filament by a direct current, and found that when a galvanometer was connected between the middle plate and the + end of the filament a small current flowed through it, but *no* current when it was connected between the — end and the plate. He described this in a U.S.A. Patent, Specification No. 307,031, filed November 15th, 1883, as a means of notifying any change in the voltage of a system of electric light mains, but he made *no application* of any kind in telegraphy, nor did he in any way explain how it arose. This phenomenon came to be called the Edison Effect.



THE EDISON EFFECT.

Nothing was known at that time about electrons. The electron was not discovered until 1897.

Dr. Fleming's Study of the Carbon Filament Electric Lamp

In 1882 Dr. J. A. Fleming was appointed scientific adviser of the Edison Electric Light Company of London, and began to study the physics of the carbon filament electric lamp.

He was the first to notice that in some cases of blackened carbon filament lamps a white line of no deposit was formed on the glass, and he called this a molecular shadow, and pointed out that it implied that the carbon particles were shot off in straight lines. He described this effect in two papers in the *Philosophical Magazine* (*Phil. Mag.*, Vol. 16, p. 48, 1883; *Phil. Mag.*, Vol. 20, p. 141, 1885).

Edison had never noticed this at all.

Further Discoveries by Dr. Fleming

About 1886 or 1887 Fleming discovered that the particles shot off from the carbon filament conveyed a negative electric charge and could discharge a positively electrified body connected to the metal plate. He also found that the so-called Edison Effect existed in the *arc* lamp. These things were described in a paper to the Royal Society of London, "On Electric Discharge between Electrodes at Different Temperatures" (*Proc. Royal Society*, Vol. 47, p. 118, 1889), and in a lecture at the Royal Institution in February, 1890 (*The Electrician*, Vol. 24, p. 393, 1890).

In 1896 Fleming sent to the Physical Society a long paper summarising all the results of his investigations on the above effects, called "A Further Examination of the Edison Effect in Glow Lamps" (*Phil. Mag.*, Vol. 42, p. 52, 1896).

Dr. Fleming's Invention of the Thermionic Valve

After the initiation of wireless telegraphy by electromagnetic waves by Marconi in 1896, Fleming began investigations which led him to the invention of the thermionic *valve*, consisting of an incandescent lamp with a carbon filament surrounded by a metal cylinder carried on a third terminal. This was first used to detect wireless signals in 1904 and patented by Fleming in Great Britain in 1904, Patent No. 24,850, November 16th, 1904, and in the United States April 19th, 1905, No. 803,684, and in other countries.

It was described to the Royal Society of London in 1905. "On the Conversion of Electric Oscillations into Continuous Currents by means of a Vacuum Valve (*Proc. Roy. Soc. Lond.*, Vol. 74, 1905), and to the Physical Society in 1906: "The Construction and Use of Oscillation Valves for rectifying High-Frequency Electric Oscillations" (*Phil. Mag.*, May, 1906).

The validity of the U.S.A. patent of Fleming for the two-electrode thermionic valve was upheld by a great judgment given in September, 1916, by Judge Mayer in the United States District Court, and this was upheld the following year by the unanimous decision of three judges in the Court of Appeals.

The Fleming valve was employed in 1907–08. Fleming first made use of tungsten filaments in thermionic valves and patented that method of employing them as detectors called the *anode bend* rectification. British Patent No. 13,518 of 1908.

The claims of Fleming as the inventor of the two-electrode thermionic valve were also upheld by Mr. Justice Sargant in 1918 in the British High Court of Justice.

POTENTIOMETERS

By FRANK PRESTON, F.R.A.

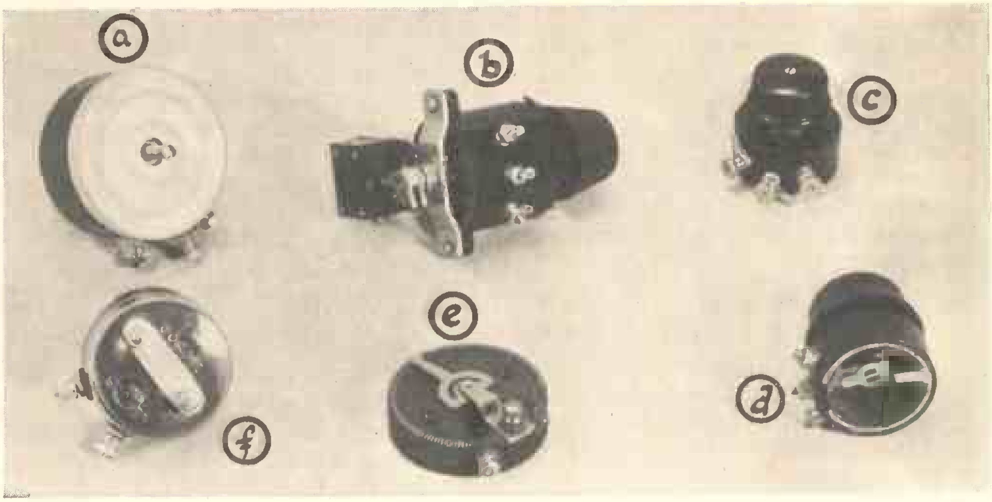


Fig. 1.—SOME EXAMPLES OF POTENTIOMETERS AND VARIABLE RESISTANCES.

a, Varley potentiometer (may be ganged) ; *b*, Wearite potentiometer with Q.M.B. switch ; *c*, Lissen potentiometer (not wire wound) ; *d*, Colvern 250 ohm potentiometer ; *e*, Lissen pre-set resistance for baseboard mounting ; *f*, Lewcos potentiometer with " rocking disc " contact.

THE underlying principles of resistances and potentiometers are almost identical.

A potentiometer is merely a resistance from which a tapping is taken ; the tapping can be either a fixed or variable one.

Ohm's Law

We cannot think of resistances without also thinking of Ohm's Law, because the two are so closely bound up. In simple language, Ohm's Law states : " The current flowing through any electrical circuit is (in amperes) equal to the applied voltage divided by the circuit's resistance (in ohms)." In mathematical language the Law reads : $C = V/R$. The latter equation enables us to determine the third quantity from a knowledge of the other two. This will be clear if we re-write it to read $R = V/C$ or $V = C \times R$.

A Typical Example

As an example, let us consider the circuit in Fig. 3, and compare it with Fig. 4—both represent the same arrangement. We will first assume that the ohmic value of the resistance is unknown, and that the voltage of the battery is 50. By connecting the milliammeter, battery and resistance in series, we obtain a reading of 1 milliampere. And now by applying the formula $R = V/C$, we find that the value of the resistance is 50 divided by 1 milliampere (1/1,000 of an ampere), or re-written, $50/1 \times \frac{1{,}000}{1}$, which equals 50,000 (ohms).

Suppose we take another example at random, just to fix the procedure firmly on our minds. By connecting an unknown resistance in the same circuit as Fig. 3, and increasing the battery voltage to 100, we find that the reading on the milliammeter is, say, 7·5 milliamps. The resistance must be, therefore, 100 divided by 7·5 thousandths, or multiplied by 1,000/7·5, and this gives us a result of $\frac{100,000}{7 \cdot 5}$, or in round figures, 13,333·3 ohms.

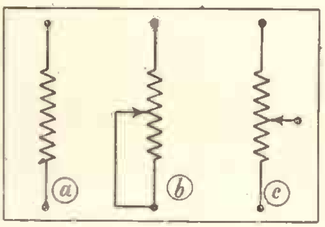


Fig. 2.—SYMBOLS USED FOR DENOTING RESISTANCES AND POTENTIOMETERS.

Voltage Drop

In practice the above calculation is employed principally to determine the value of resistance required to give a specified "voltage drop."

For instance, let us suppose that in the circuit of Fig. 5 the anode of the S.G. valve requires a voltage of 120, and at that voltage the valve passes an anode current of 4 milliamperes. Now the H.T. voltage supplied by the mains equipment is 250, so it is required to "drop" 130 volts across resistance R6. What must be the value of R6? Easy, if we use our previous formula, R = V/C. It is 130/4 milliamps, or $130/1 \times \frac{1,000}{4}$, which equals $\frac{130,000}{4}$, 32,500 ohms. In practice we should choose either a 30,000 ohm or 35,000 ohm component, whichever was more convenient.

Power Rating

Before we can decide on the type of resistance required, we must know how much *power*, in watts, it will have to deal with. The power is equal to the number of volts "dropped," multiplied by the number of amperes passing, so in this case it is equal to $130 \times \frac{4}{1,000}$, or 520/1,000, which is approximately half a watt.

The wattage can also be calculated when only the current and resistance are known; it is found by substituting in the formula: power (in watts) equals the square of the current multiplied by the resistance, or $W = C^2R$.

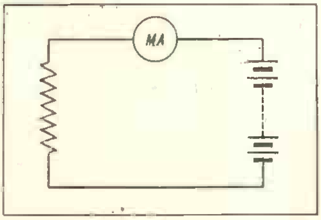


Fig. 3.—CIRCUIT WITH RESISTANCE AND MILLIAMMETER.
Compare with Fig. 4.

As an example we will suppose that when a 10,000 ohm voltage dropping resistance has been inserted in a high tension feed circuit, the current flowing is 8 milliamps. By substitution in our new formula $W = C^2R$, we get

$$W = \left(\frac{8}{1,000}\right)^2 \times 10,000,$$

which can be simplified to

$$\frac{64}{1,000,000} \times \frac{10,000}{1},$$

and by cancellation this gives us the result of $\frac{64}{100}$ which is approximately $\frac{2}{3}$ (of a watt).

As might be imagined, resistances are made in various power ratings as well as in different values of ohmic resistance. The higher the rating, the more expensive the resistance. (See also the article on "Resistances," on p. 407.)

Potentiometers

A potentiometer, is, in appearance, almost identical with a variable resistance. It has, however, three terminals instead of two. Of these, one is in contact with the slider, and the other two are joined to the ends of the resistance element. The latter also is the same as that of a variable resistance, consisting either of graphite or wire.

The object of a potentiometer is, as the name implies, to provide a potential rather than a voltage. By a "potential" we generally mean (although somewhat unscientifically, perhaps), an electrical pressure which is accompanied by a very small current. The usual type of variable potentiometer is denoted by the symbol shown at (*c*) in Fig. 2. It is connected in a circuit of the type represented in Fig. 7. When the slider is in position A, the potential between points S and 2 is zero, but as the slider is moved towards position B, the potential gradually reaches

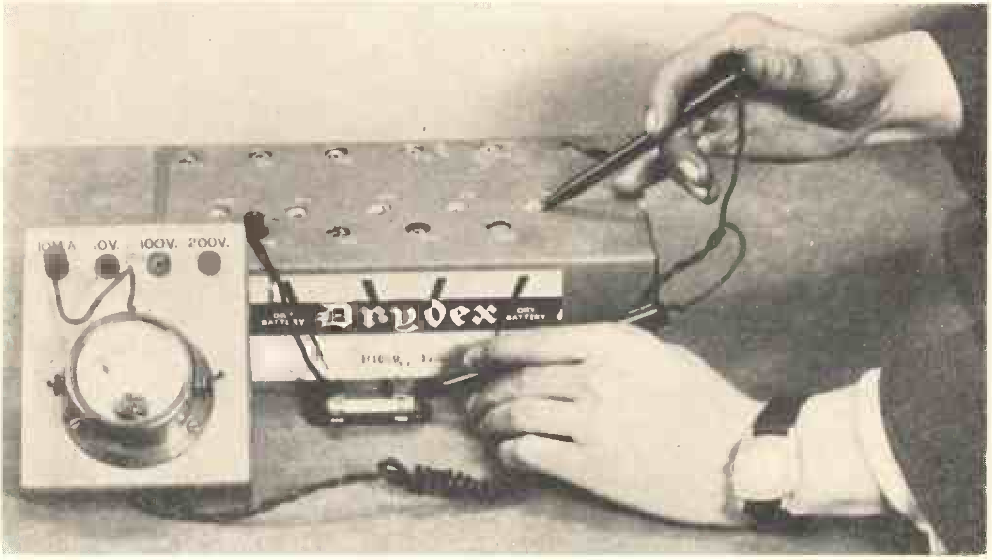


Fig. 4.—Finding the Value of a Resistance by Means of a Battery and Milliammeter.

Note that a multi-range meter is used so that the exact battery voltage can be measured before testing the resistance.

the maximum of the supply from the battery.

Use of Potentiometers.

The principal use of potentiometers in wireless circuits is to provide the screening grid potential to S.G. valves, and to act as volume controls in various ways.

When employed for the former purpose, the potential is proportional to the position of the slider. This can be explained more fully by making reference to Fig. 8. When the slider S is at that end of the resistance element marked 1, the screening grid potential is equal to that of the high-tension battery, namely 120 volts, but when moved to the end marked 2, the potential is 0. When set midway between

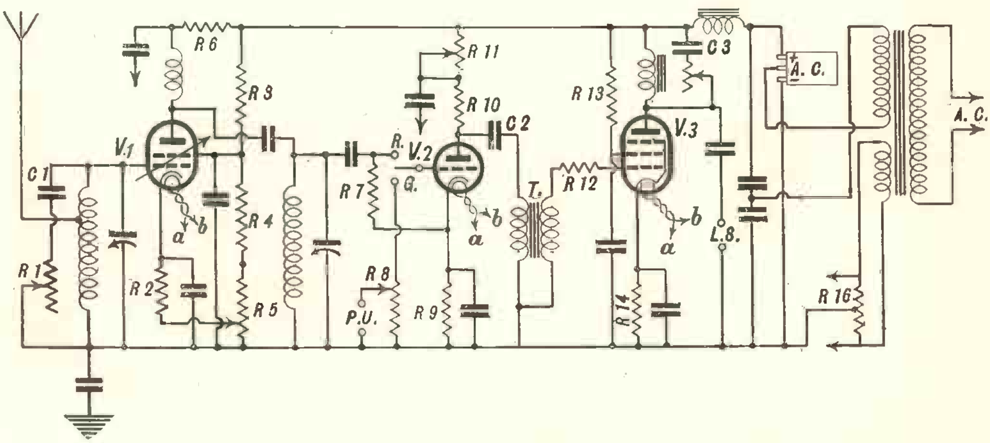


Fig. 5.—A Typical Circuit Diagram.

The method of arriving at the correct values for the various resistances and potentiometers shown is discussed in this article.

ends 1 and 2, the S.G. potential is 60 volts. In the same way it will be seen that when the slider is three-quarters of the way up from 2, the S.G. potential is 90 volts.

Graded Potentiometers.

As explained, the potential derived from the usual type of potentiometer is proportional to the position of the slider. Thus the resistance between the slider and one end of the resistance element is varied by the same amount when the control knob is turned from 0 to 10 degrees, as when it is turned from, say, 150 to 160 degrees. This is convenient when the potentiometer is used for most purposes,

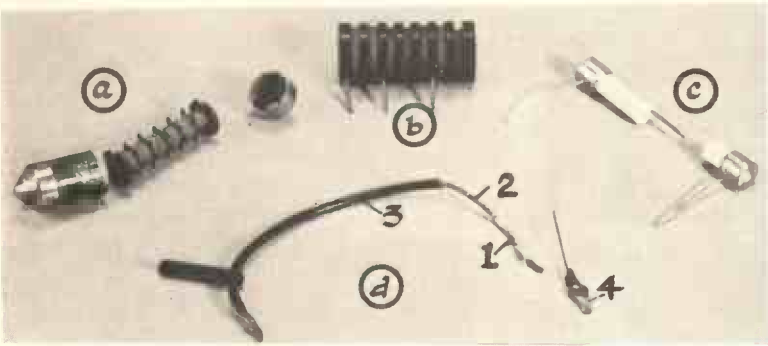


Fig. 6.—THE INTERNAL CONSTRUCTION OF VARIOUS TYPES OF RESISTANCES.

a, inside of a Ferranti wire wound resistance ; *b*, a home constructed wire wound resistance ; *c*, a broken Dubilier metallised resistance (a heavy hammer was used and the resistance broke after the second blow) ; *d*, Spaghetti resistance showing 1, asbestos cord core ; 2, wire winding ; 3, insulated sleeving ; 4, connecting tag.

but there are some cases for which it is far from ideal. For instance, when the usual type of potentiometer is used for controlling the volume from a pick-up, it has little effect over the first quarter revolution or so, whilst when the slider approaches the end of its travel, a very slight movement causes a tremendous change in volume.

To overcome this drawback, a number of " graded " potentiometers are available. These are so constructed that the change of resistance for any given amount of slider movement decreases as the slider is moved from " maximum " to " minimum" volume, or from 0 to the highest scale reading. In most instruments this is provided by winding the resistance wire on a tapering strip of insulating material, and so making the turns of diminishing lengths.

Slider Contact.

The methods of making contact between the resistance element and the slider are generally the same as those employed in the case of resistances.

Realising, however, that the rubbing action of the usual slider is bound to wear away the very fine resistance wire sooner or later, one or two firms have devised better systems.

The most notable of these is that evolved by Messrs. Lewcos, and used in the potentiometer shown at (*f*) in Fig. 1. In this instrument a rocking disc is used. By mounting the disc at an angle to the spindle it is "rocked" round the resistance element ; it does not rub at all, and consequently the wear on the wire is nil. A sketch of the idea is given in Fig. 9.

Ganging.

To make it possible to control two or more potentiometers by a single knob, one or two firms, notably Messrs. Varley, make their potentiometers in such a way that any number can be ganged together. The method employed by the latter firm and illustrated at (*a*) in Fig. 1 is to allow the threaded spindle to project from the bottom ; by using a threaded " union " this can be attached to the spindle of another component.

Ganged potentiometers are very useful for controlling the volume of both radio and gramophone reproduction. By using one potentiometer to control the grid bias of a variable-mu S.G. valve and the other to act on the pick-up, one knob can be used for both purposes. This simplifies the panel lay-out and makes for greater simplicity of operation. The above is just one example of the use of ganged potentiometers, and there are many others which will occur to the reader.

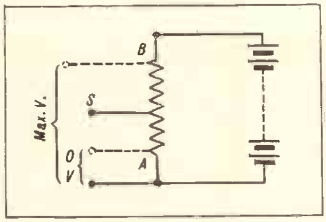


Fig. 7.—How a Potentiometer is generally connected.

Special Potentiometers

Before leaving the subject of variable potentiometers, mention must be made of a special kind which is becoming increasingly popular. I refer to the potentiometer with which is combined a toggle switch. The switch can be used for connecting the set to the power supply, and the potentiometer, for a volume control. By moving the control knob just past the position of minimum volume, a lever on the end of the spindle turns off the switch. Combined potentiometer-switches of this kind are also very useful for providing a variable grid bias for variable-mu valves of the battery-fed type ; the switch can be used to break the circuit between the potentiometer and G.B. battery, thus avoiding waste of G.B. current (through the potentiometer windings), whilst the set is out of use.

A Weairite potentiometer-switch is shown at (*b*) in Fig. 1 ; others are made by Messrs. Bulgin.

Fixed Potentiometers

In many types of battery receivers better results are to be obtained by connecting the grid leak to a point of potential somewhere between the extremes of L.T. positive and negative. The exact point is not very critical, and so a fixed potentiometer can be used for the purpose. The latter generally takes the form of a small non-inductively wound resistance from which a tapping is taken ; its connections are as shown in Fig. 10. Probably the best known potentiometer of this type is the Lewcos.

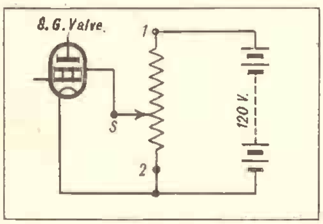


Fig. 8.—Use of Potentiometer to provide Screening Grid Potential to S.G. Valves.

Another use for a fixed potentiometer or centre-tapped resistance is to provide an artificial centre-tap for untapped L.T. windings of mains transformers. A component specially designed for this purpose is made by Messrs. Varley.

HOW TO CHOOSE RESISTANCES AND POTENTIOMETERS FOR WIRELESS CIRCUITS

We will now consider the circuit diagram in Fig. 5 and decide on the correct components to employ in the positions marked from R1 to R16.

The circuit does not necessarily represent an ideal, or even a good arrangement. It does, however, incorporate most of those features to be found in a very high-class S.G.-D.-Pen. A.C. receiver.

Pre-detector Volume Control

The volume control resistance R1 is used in connection with the condenser C1 to damp the tuning of the aerial coil. Its principal use is to reduce the input from the local station and so prevent overloading of the first valve. Being in shunt with a tuned circuit, it must clearly be non-inductive (not wire wound) and should have a maximum value in the region of 50,000 ohms.

Variable Automatic Grid Bias

R2 and R5 act together to provide a variable grid bias to the variable-mu S.G. valve. R2 serves to decouple the cathode and also to provide a minimum degree of bias when the slider of potentiometer R5 is turned to the end marked "2." Suppose the total H.T. current consumption of V1 is 5 milliamperes (4 milliamperes to the anode and 1 milliampere to the screening grid) and that the minimum amount of bias required is $1\frac{1}{2}$ volts; R2 will therefore require to have a resistance of $1·5/1 \times 1,000/5$ (from $R = V/C$), or 300 ohms. The resistance should for preference be non-inductive, but this is not essential, since even a wire wound resistance of 300 ohms would have an inappreciable inductance. R5 should have such a resistance that V1 is biased to maximum extent when the slider is at the end marked "1." If the maximum bias is, say, 12 volts, R5 will have to provide 10·5 (12 − 1·5) volts, so its resistance must be $10·5/1 \times \frac{1,000}{5}$, or 2,100 ohms. In practice we should probably choose a 2,000-ohm component for convenience.

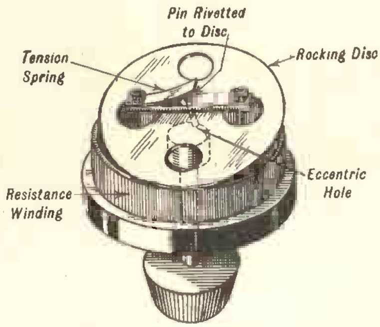


Fig. 9.—Principle of Rocking Plate of Lewcos Potentiometer.

Screening Grid Supply

The fixed resistances R3 and R4 together form a fixed potentiometer which supplies H.T. to the screening grid of V1. (In the case of a V.-M. valve the screening grid potential should remain constant.) When a potential of 80 volts is required and the voltage of the supply is 250 the ratio of R4 plus R5 to R3 must be as 80 is to 170 (250 − 80). A suitable total resistance for R3 plus R4 plus R5 is 100,000 ohms, and therefore, by simple proportion, R3 should be of 68,000 ohms and R4, 30,000 ohms (32,000 − 2,000 for R5). After making the calculation as above we should choose standard resistances which were nearest in value to the calculated figures.

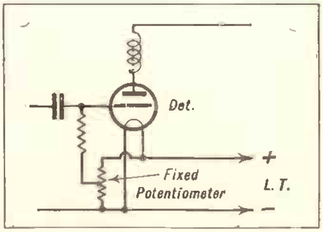


Fig. 10.—Showing Use of Fixed Potentiometer for connecting Grid Leak to a Point of Potential somewhere between the Extremes of L.T. Positive and Negative.

Grid Leak

We have considered R6 before, so we can pass on to the detector grid leak R7. The value of this is dependent upon the type of rectification desired. When normal leaky grid rectification is employed a resistance in the region of 2 megohms (2 million ohms) is correct, but for power grid detection the value must be reduced to $\frac{1}{2}$ or even $\frac{1}{4}$ megohm. A grid leak must always be absolutely non-inductive.

Detector Grid Bias

When the set is to be used for gramophone reproduction, the valve V2, which normally functions as detector, acts as a low-frequency amplifier, and therefore requires a certain amount of negative grid bias. The latter is provided by the fixed resistance R9, which may be either wire-wound or non-inductive, the latter being rather "safer" from the point of view of stable operation.

The value of R9 will be found in exactly the same way as that of R2. Thus, if a bias voltage of 1 is required, and at this figure the valve passes 2 milliamperes, the resistance should be $1 \times 1,000/2$, or 500 ohms.

Pick-up Volume Control

The actual resistance of the pick-up volume control potentiometer R8 is dependent principally upon the pick-up employed. For instance, with a high impedance unit, such as the Marconiphone, the resistance should be not less than 250,000 ohms, whilst when a lower impedance pick-up, such as the B.T.H. is used, 50,000 ohms is a more suitable value. In nearly all cases the makers specify the correct value of resistance required.

As mentioned earlier, a "graded" potentiometer will give the "smoothest" control of volume, and is to be preferred for position R8.

Parallel Feed

The fixed resistance R10 is used in conjunction with the coupling condenser C2 and L.F. transformer T to provide resistance fed, or parallel fed transformer coupling. The optimum resistance of R10 is from twice to two-and-a-half times the impedance of the detector valve V2. Thus if a Cossor 41MH valve (impedance 18,000 ohms) were used for V2, R10 should be of about 40,000 ohms. A non-inductive or low-inductance resistance is best for this position.

De-coupling

R11 is a variable resistance used to de-couple the anode circuit of V2, and to provide a variable anode voltage. Its value can be calculated in the same way as that of R6. Any type of variable resistance, either wire-wound or otherwise, will be suitable.

" Stopper " Resistance

The fixed resistance R12 is a " stopper " to prevent the passage of high-frequency currents into the pentode amplifier circuit. Any non-inductive resistance of from 10,000 to 100,000 ohms will serve here. It must offer a high impedance in proportion to that of the small condenser formed by the grid and cathode of V3. The best value *can* be found by calculation, but in practice it is more usual to find it by experiment. When the correct value has been chosen, it should be possible to touch the anode terminal of V3 without causing a whistle to be emitted by the speaker or a reduction in signal strength.

De-coupling a Pentode

R13 serves to de-couple the priming grid of the pentode. Any value from 5,000 to 10,000 ohms is suitable, and the resistance may be either inductive or non-inductive.

Pentode Bias Resistance

The automatic bias resistance R14 acts in the same way as resistances R2 and R9, and its value is calculated in the same way.

Assuming V3 to take 35 milliamps H.T., and to require 11 volts grid bias, R14 should be of approximately 300 ohms.

All those resistances previously considered carry only small amounts of current, so it has scarcely been necessary to consider their power ratings. But as R14 has to deal with a comparatively large amount of current, we had better see what its power rating should be. Using our formula $W = C \times V$, we get $W = 35/1{,}000 \times \frac{11}{1}$, which cancels out to rather less than half a watt. Nearly any type of small resistance will therefore be suitable.

Tone Correction

Since a pentode valve generally tends to give emphasis to the higher musical frequencies, it is usual to employ a tone correction device with it. This latter generally consists of a variable resistance and fixed condenser connected in series across the primary of the output transformer, or across the output choke, as shown at R15 and C3 in Fig. 5.

The object is to provide a fairly easy leakage path for higher frequencies, whilst at the same time arranging that the " leakage " shall be as small as possible for lower frequencies. This can be provided for by so proportioning the values of C3 and R15 that they resonate to a low frequency.

When C3 is ·01 mfd., R15 should have a maximum resistance of 50,000 ohms. By adjusting the variable resistance, a varying degree of high note attenuation can be obtained.

Practically any type of 50,000 ohm resistance will be correct for R15.

Artificial Centre Tap

We have previously seen that the object of R16, which is a centre-tapped resistance, is to provide an artificial centre tapping for the 4-volt winding of the mains transformer.

SERVICING

ULTRA TIGER, PANTHER AND BLUE FOX RECEIVERS

THE range of ultra receivers consists of a two-, three- and four-valve set, the circuit diagrams of which are shown in the following pages. It would be advantageous first of all to consider the main characteristics of these three receivers.

Fig. 1.—Removing the Three Control Knobs to allow the Chassis to be withdrawn from its Cabinet.

The Blue Fox

The Ultra Blue Fox is made in both A.C. and D.C. models, each of which consists of a grid lead detector followed by a pentode output valve. In the A.C. model an A.C. pentode is used, and in the D.C. type the Mazda D.C. pentode, which is its equivalent, is substituted. The circuit in this receiver embraces a smoothing arrangement which employs a choke and condenser, the loud speaker being of the permanent magnet type. Simplicity of arrangement is an outstanding feature, and servicing is confined to very narrow limits.

Tiger and Panther

The Tiger and Panther receivers are somewhat more elaborate in design, the former employing an input filter circuit which feeds a screened-grid stage of H.F. amplification followed by a screened-grid detector valve, the latter being resistance-coupled to a pentode output stage. The Ultra Panther does not utilise the same type of filter, but has a second stage of H.F. amplification. In both Tiger and Panther, the loud speaker exciting coil is used as a smoothing choke for the H.T. supply and in the A.C. models, as is usual, a "bucking winding" is employed to cut out the last trace of hum from the loud speaker. As will be seen from the circuit diagrams, the D.C. model has a slightly different arrangement, the loud speaker field being excited by the current supplied to the cathode heater circuits. The voltage variation for the different supply voltages is absorbed by a Philips Barretter, a miniwatt No. 1904 H.T. smoothing is occasioned by a very generous choke and condenser circuit. The Panther receiver is not made in a D.C. model.

Preliminary Inspection

When called upon to service an All Mains receiver, a great deal of time and trouble can be saved by a careful examination and consideration of the likely causes

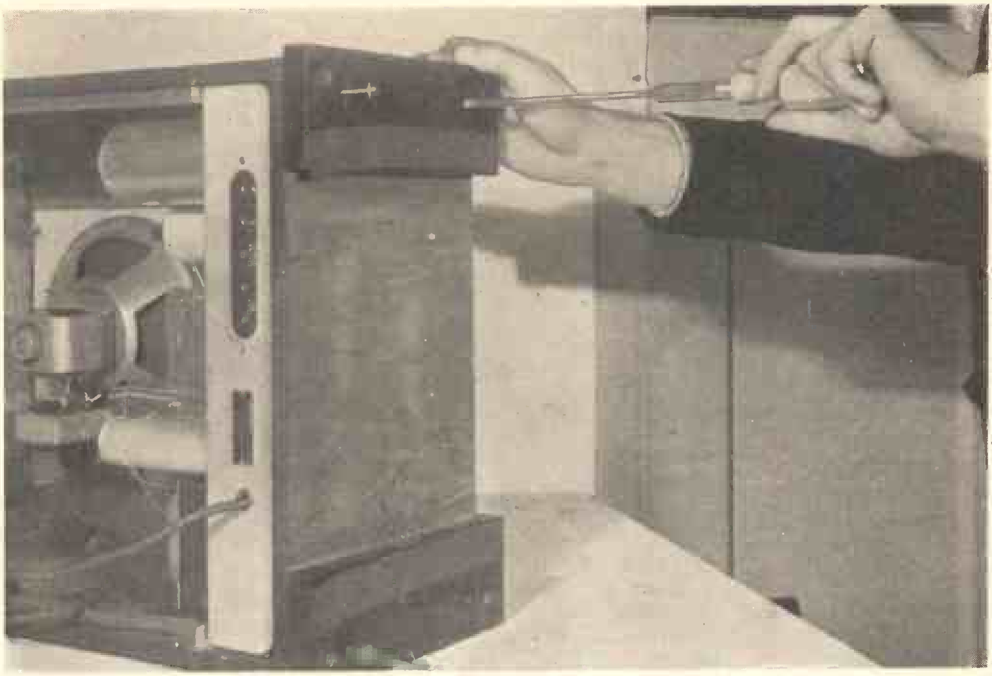


Fig. 2.—Four Bolts hold the Chassis in Position and are removed from the Under Side of the Cabinet.

of the fault. In D.C. receivers the pilot light is nearly always wired in series with the heater circuits, the failure of this lamp will be responsible for the total inoperation of the set ; on the other hand, a failure of either of the valve heaters will make the pilot light inoperative. In an A.C. receiver, although the pilot light may still work satisfactorily, a defective valve heater circuit can generally be found by switching on the receiver for a few moments and noting if each valve attains the degree of warmth naturally associated with its proper functioning.

Possibility of Mechanical Damage

Having ascertained that from all external appearances all the valves of the set are operating in normal manner, it is as well before going to the trouble of taking the set out of its cabinet to make a careful survey as to the possibility of mechanical damage to any of the working parts. Two possible sources of mechanical defect are the volume control and the wavechange switch.

Volume Control and Wavechange Switch

To judge whether a volume control is mechanically defective, it should be turned slowly from maximum to minimum to see whether the movement is smooth or otherwise. Similarly, the movement of the wavechange switch can be checked. In the case of the Blue Fox this is a two-position switch with a stop at either end of the movement, but in the Tiger and Panther a three-position switch is employed which has a spring stop for short wave, long wave and gramophone.

Use of Gramophone Terminals

The connections provided for fitting a gramophone pick-up can be of great assistance in servicing a set. By attaching the gramophone pick-up it can at once be decided whether the fault is in front of or behind the detector valve. If the gramophone side of the receiver works satisfactorily, it is definite that the fault must rest either in the H.F. valve circuits or in the case of the Blue Fox, in the detector valve circuit.

Two Classes of Faults

Faults in a radio receiver can be divided into two very definite classes, the first in which the receiver will operate, but in a very unsatisfactory manner and the second in which no results whatever are obtained. The procedure adopted depends to a great extent upon the symptoms displayed by the receiver, but a certain method in approaching the fault will be of considerable assistance in its solution.

See that the Valves are in their correct position

In the first place it should be ascertained that the valves are in their correct position in the chassis. Though it seems unreasonable to assume that they should be changed over, it is by no means an uncommon occurrence.

Fig. 3.—Draw The Chassis straight Back until the Control Spindles are Clear of the Woodwork.

Fig. 4.—The Chassis can be Withdrawn without Disconnecting the Loud Speaker.

Examine Flexible Leads

Next examine all the flexible leads attached to the external terminals on the screened-grid and pentode valves. They should be firmly attached under their respective nuts, and it is possible in unpacking the receiver that one or other of them has not been correctly replaced.

Checking the Heater Circuits

If any doubt is entertained as to the performance of any of the valves, the heater circuits can readily be checked by means of a simple voltmeter and battery. This same test will also serve to show whether there is an internal short circuit between any of the electrodes and the cathode or heater. An examination of the leads connecting the loud speaker will show at a glance whether they are properly attached to their connecting tags.

Removing the Chassis

When all these tests fail to reveal any source of error, it will be necessary to take out the chassis from the cabinet for an internal inspection. In this respect it should be mentioned that all Ultra Receivers are made in such a way that the chassis can be withdrawn without disconnecting the loud speaker. This is of considerable assistance because the loud speaker is nearly always helpful in determining the performance of the chassis. When the chassis of any Ultra Receiver has been withdrawn, the circuits can be checked by applying a voltage test to the anodes of each valve. (See Table of Voltages on the facing page.)

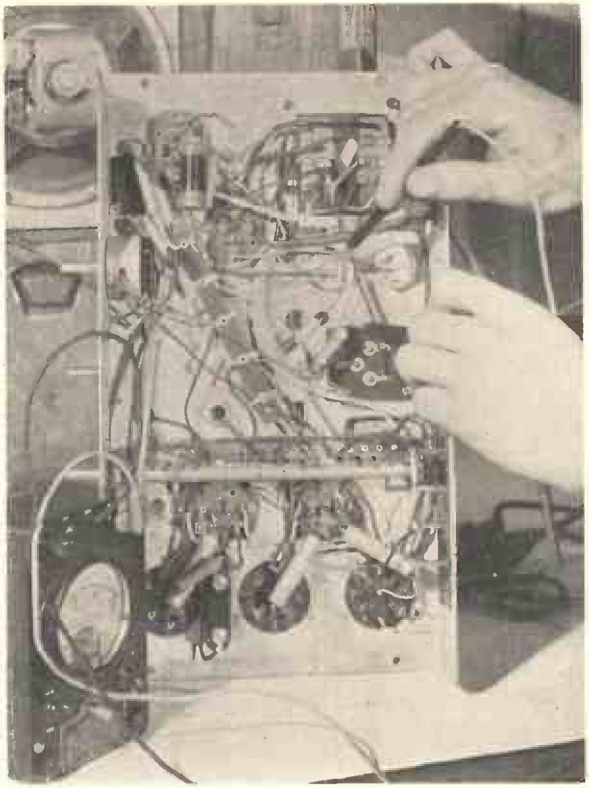


Fig. 5.—Measuring Voltages at various Points on the Circuit, with a High Resistance Voltmeter.

This is a very simple way of checking the receiver for faults.

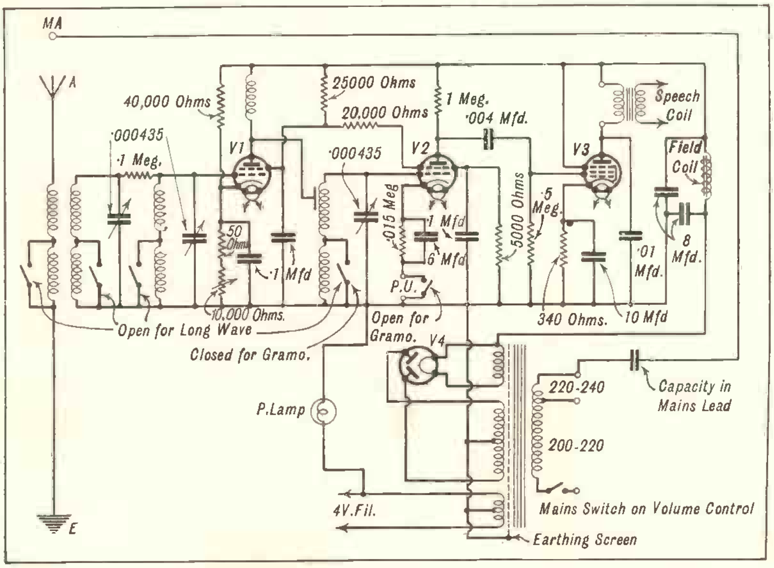


Fig. 6.—Theoretical Circuit Diagram of Ultra Tiger A.C. Receiver.

High Resistance Voltmeter should be used

To do this it is necessary to employ a voltmeter having a very high resistance, the reason being that in common with many other types of modern receivers, the Ultra sets employ resistances for the purpose of breaking down the H.T. voltage, or for coupling one valve to another, and, if a low-resistance instrument is used, a totally false reading is given owing to the actual current consumed by the voltmeter; 1,000

Voltage Readings

Readings taken with 1,000 ohms per volt Meter with Maximum Scale Reading of not less than 300 volts

	Valves used	All Voltages to Chassis.	V1.	V2.	V3.	V4.
TIGER A.C.	V1. Mazda A.C./SG VM (coated).	Cathode	40	2	11	—
	V2. Mazda A.C./SG.	Anode	195	25	190	—
	V3. Mazda A.C./PEN.	Screen	95	20	195	—
	V4. Mazda UU2.	Rectifier-Filament	—	—	—	295

	Valves used	All Voltages to Chassis.	V1.	V2.	V3.	
TIGER D.C.	V1. Mazda D.C.2/SG VM (coated).	Cathode	40	2	11	—
	V2. Mazda D.C.2/SG.	Anode	205	25	195	—
	V3. Mazda D.C.2/PEN.	Screen	100	20	205	—
		Set-Side of Speaker Coil	—	—	—	70

	Valves used	All Voltages to Chassis.	V1.	V2.	V3.	V4.	V5.
PANTHER	V1. Mazda A.C./SIVM (coated).	Cathode	45	45	2	10	—
	V2. Mazda A.C./SIVM (coated).	Anode	215	215	25	200	—
	V3. Mazda A.C./SG.	Screen	110	110	22	215	—
	V4. Mazda A.C./PEN.	Rectifier-Filament	—	—	—	—	320
	V5. Mazda UU2.						

	Valves used	All Voltages to Chassis.	V1.	V2.	V3.
BLUE FOX A.C.	V1. Mazda A.C.2/H.L.	Cathode	—	10	—
	V2. Marconi MPT4 or Mazda A.C./PEN.	Anode	165	180	—
	V3. Mazda UU2.	Screen	—	190	—
		Rectifier-Filament	—	—	215

	Valves used	All Voltages to Chassis.	V1.	V2.
BLUE FOX D.C.	V1. Mazda D.C.2/H.L.	Cathode	—	10
	V2. Mazda D.C.2/PEN.	Anode	165	180
		Screen	—	190
		Rectifier-Filament	—	—

ohms per volt is a very satisfactory resistance, and the voltmeter should have a maximum reading of 300 volts—its total resistance being therefore 300,000 ohms.

Leaks

The resistances in an Ultra receiver are all marked by a colour code, as shown in the table on p. 804.

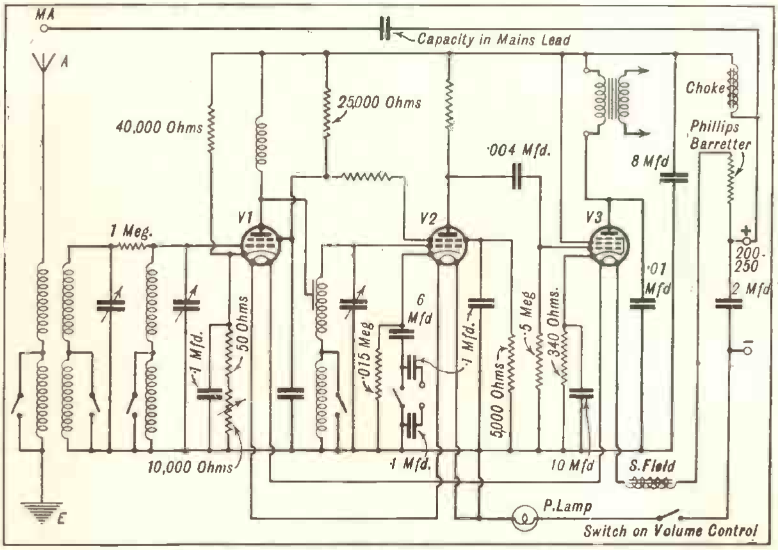


Fig. 7.—Theoretical Circuit Diagram of Ultra Tiger D.C. Receiver.

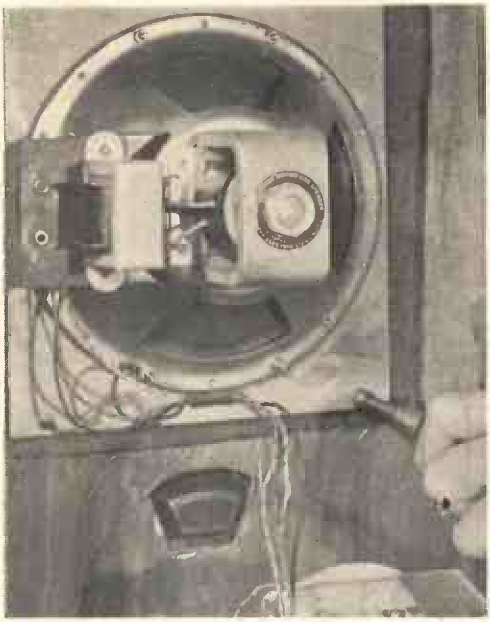


Fig. 8.—Taking Out the Loud Speaker (1).

This is done by unscrewing four nuts on the baffle board.

Fig. 9.—Taking Out the Loud Speaker (2).

The speaker and baffle come away as a single unit, and can be tested with the chassis.

Resistance Measurement

It is of very great assistance when checking a chassis to have one of the resistance measuring appliances of the type provided by the Weston-Tester. This excellent instrument will show at a glance within a small percentage the value of any resistance between a few hundred ohms and ·1 megohm. By this means it is a matter only of moments to measure every resistance in a receiver.

Condensers

Condensers are somewhat more difficult to check as it is almost impossible to carry a capacity bridge when servicing a wireless set, but much can be determined by consideration of their performance. Any tendency to instability would indicate the failure of a decoupling condenser, and the substitution of a similar capacity across each decoupler would determine the position of the faulty component.

Test for Faulty Smoothing Condenser

Smoothing condensers are not a very frequent source of trouble, but do occasionally either form a dead short circuit or an open circuit, the former being a very serious fault almost always resulting in a damaged transformer, while an OC condenser in this position will cause a considerable hum. The test for this is a

Resistance Colour Code Chart

Value.	Tip.	Body.	Tip.
1Ω .	Blue.	Red.	Green.
500,000ω .	—	Red.	Blue.
300,000ω .	Green.	Red and Blue.	Orange.
250,000ω .	—	Green.	Orange.
100,000ω .	—	Orange.	—
80,000ω .	—	Green.	Blue.
70,000ω .	—	Purple.	—
50,000ω .	—	Red.	—
40,000ω .	Green.	Red.	Orange.
30,000ω .	Blue.	Red.	Orange.
25,000ω .	Green.	Orange.	Blue.
20,000ω .	—	Red.	Orange.
15,000ω .	—	Red.	Green.
10,000ω .	—	Blue.	—
8,000ω .	—	Green.	—
5,000ω .	—	Blue.	Orange.
300ω .	—	Brown.	—

Fig. 10.—Adjusting the Speech Coil.

If the speech coil is out of centre it can be adjusted by slacking off the centre screw as shown above.

Fig. 11.—Detaching Loud Speaker from the Chassis.

When it is necessary to detach the loud speaker from the chassis a soldering iron is needed to disconnect the leads from their respective tags on the loud speaker strip.

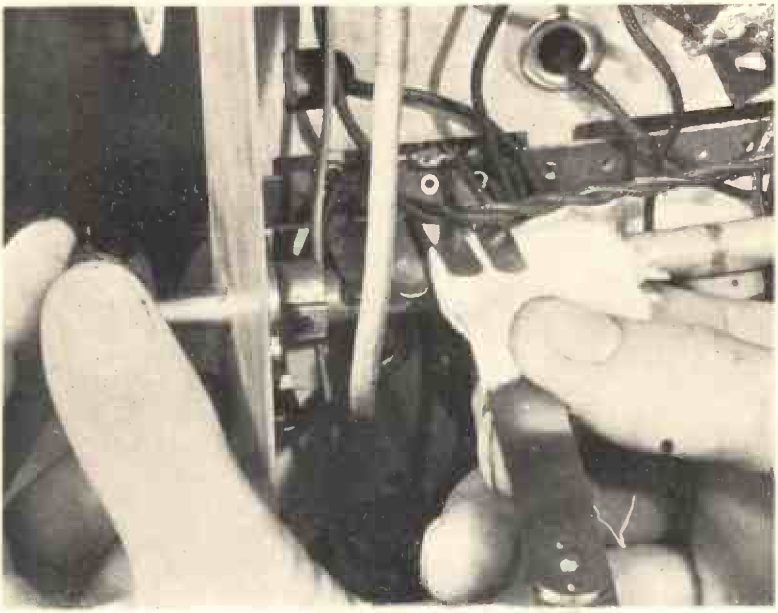


Fig. 12.—CLEANING THE WAVECHANGE SWITCH CONTACTS.

Wavechange switch contacts are easily cleaned by means of a piece of soft rag stretched over a thin steel blade. Care is necessary to avoid opening the spring contact.

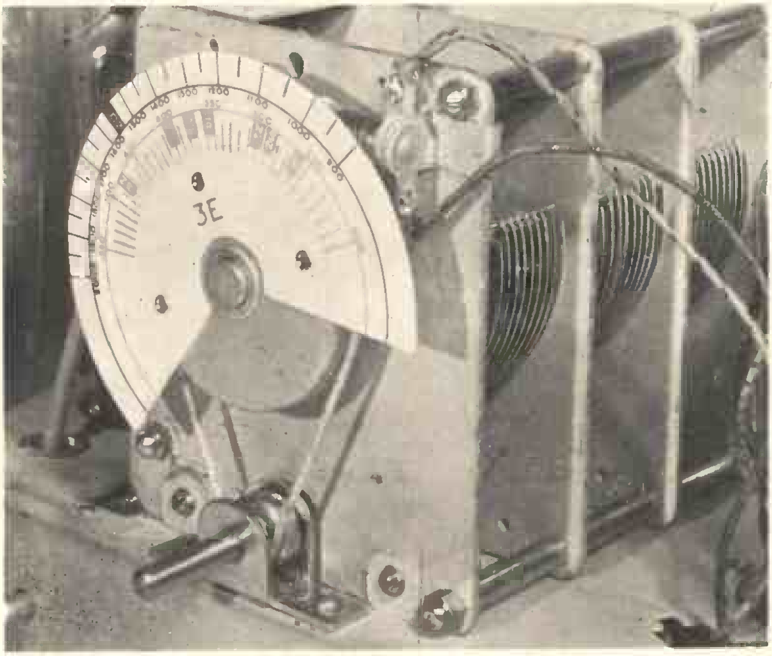


Fig. 13.—THE SCALE AND DRIVE ASSEMBLY.

To reset the wavelength scale it is only necessary to loosen the screw in the scale drum when the dial can be moved without the condenser vanes.

parallel condenser of similar capacity applied while the set is working.

Causes of Hum

While on the subject of hum, it should not be forgotten that a short circuit, or partial short circuit in the loud speaker may so reduce the smoothing that a hum occurs. This hum should not be associated with a buzz which might possibly occur if the centre tap of the cathode heating filament winding became detached from the earth tag on the mains transformer.

Replacing a Tuning Coil

Faults in the chassis are fairly well covered by the foregoing tests. Only the tuning coils remain, and it is very unlikely that these will develop a fault other than a definitely broken connection, due either to mechanical interference or damage in transit. Their connections can readily be traced from the circuit diagram, and if it should be found necessary to replace a tuning coil it can be easily detached from the chassis after unsoldering the connecting wires by taking out the three sheet metal screws which hold the bakelite coil mounting disc to the chassis. The screws are situated inside the screening can on the Panther and Tiger receiver.

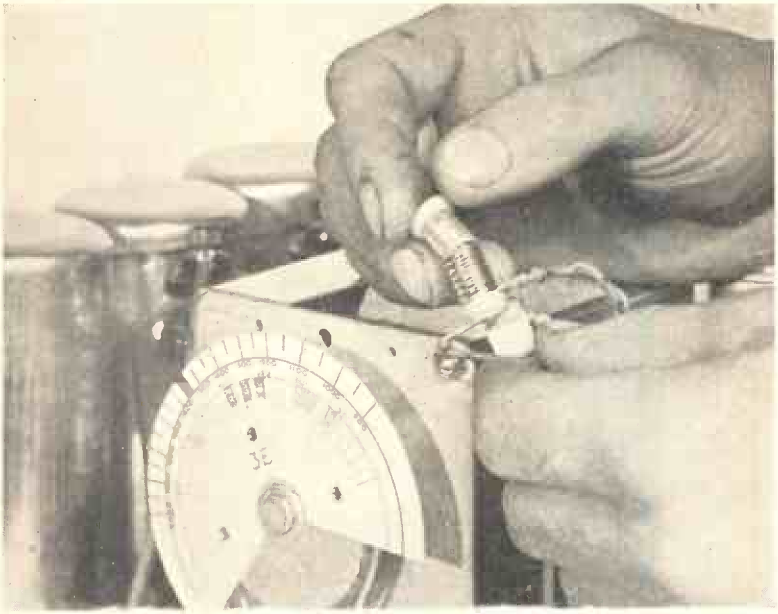


Fig. 14.—A New Pilot Bulb is fitted by detaching the Lamp Holder from its Position on the Front Condenser Plate.

Faults causing Unsatisfactory Reception

The conditions under which a receiver is working are often responsible for unsatisfactory results, whereas the instrument itself is in perfect working condition. Ultra receivers employ a special form of aerial coupling device, which gives a high degree of selectivity. This necessitates the use of a really good earth connection if satisfactory results are to be obtained.

The receivers are designed for an aerial of moderate length, and if an excessively large aerial is used, they may show an apparent lack of sensitivity on the higher end of the medium waveband.

The Trimmer Condensers

The trimmer condensers on the three-gang condenser will not alter this condition in any way. Each Ultra set is very accurately trimmed before leaving the

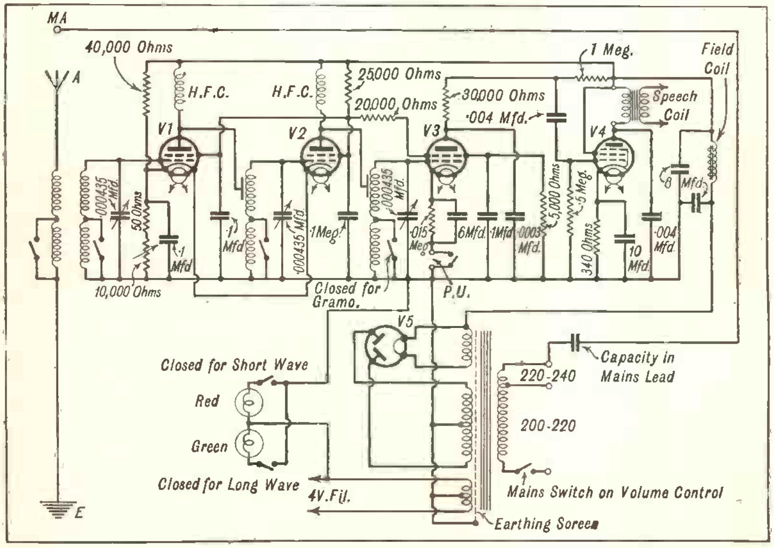


Fig. 15.—Theoretical Circuit Diagram of the Ultra Panther A.C. Receiver.

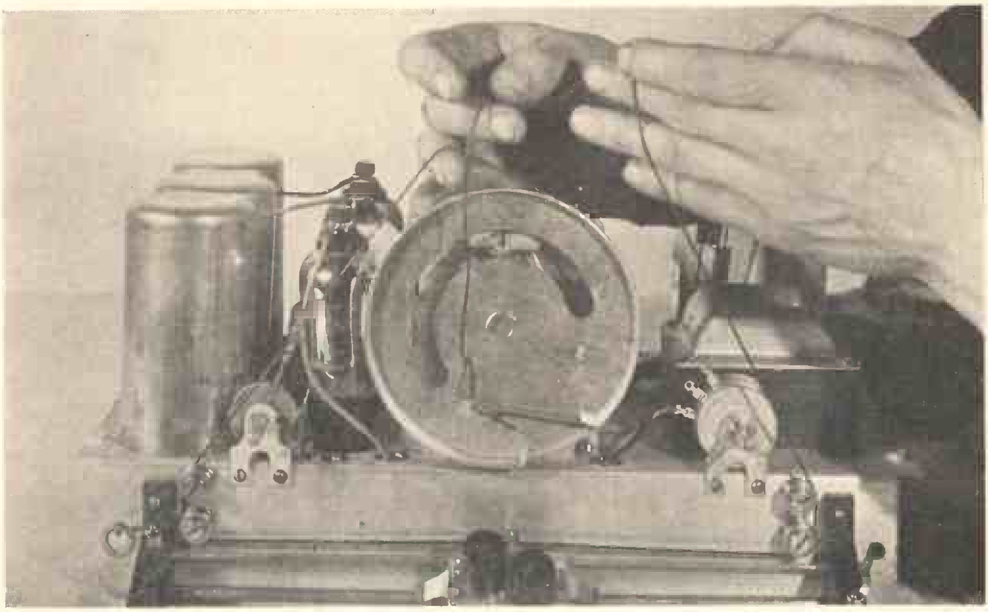


Fig. 16.—THE LIGHT POINTER MECHANISM OF THE ULTRA PANTHER RECEIVER.

This is actuated by a cord carried on the large drum nearest the cabinet front. This cord is replaced as shown above.

factory by actual measurement on a Standard Signal Generator, and the alteration of the trimmers is not recommended except in those cases where they have definitely been put out of adjustment by rough transit or other causes. Should it be necessary to readjust the trimmers, the tuning condenser should be adjusted

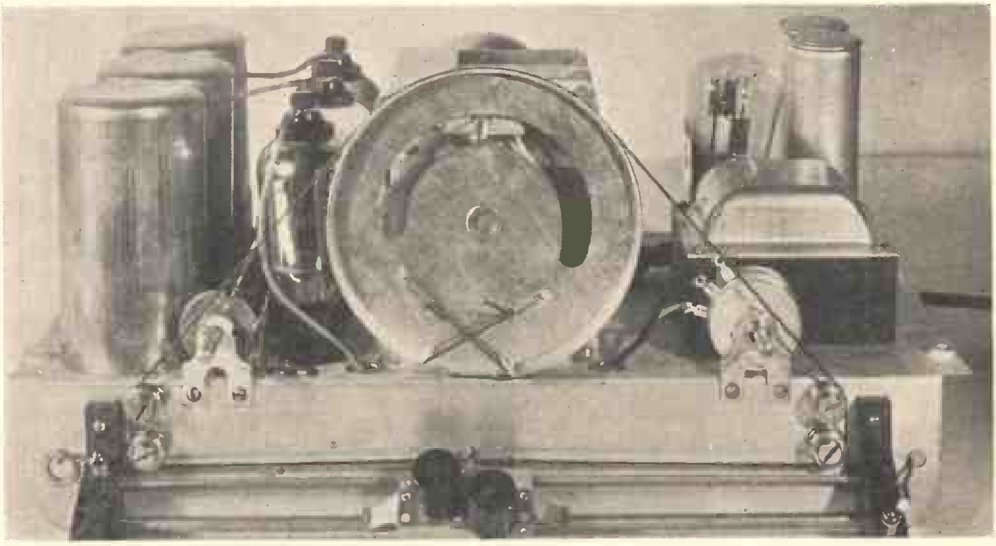


Fig. 17.—THE COMPLETELY ASSEMBLED DRIVE OF THE ULTRA PANTHER RECEIVER.

to minimum wavelength with the volume control fully advanced. The set can then be trimmed on extraneous "mush."

Distortion

Distortion may come from several sources, the most likely being a "soft" pentode valve, which would cause a rough "tearing" of the music. If the distortion is noticed mainly on low volume, it may be due to the speech coil of the loud speaker very lightly fouling the pot. Such a defect would not be noticed on heavy signals. The remedy for this latter fault is a readjustment of the centering of the speech coil.

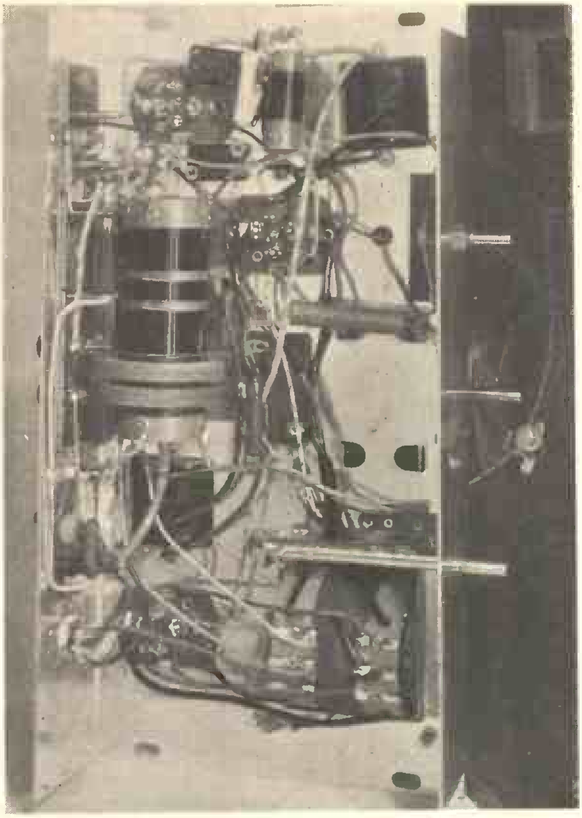


Fig. 18.—ALL "ULTRA" RECEIVERS ARE FITTED TO THEIR CABINETS IN THE SAME WAY, BUT IN THE "BLUE FOX" THE TUNING COILS ARE SITUATED UNDERNEATH THE METAL CHASSIS. ALL CONNECTIONS ARE THUS VISIBLE AND READILY ACCESSIBLE FOR TEST.

How to Adjust the Wavelength Scales

The Tiger and Panther receivers have a wavelength scale, which may require readjustment or resetting. In the case of the Tiger this is an exceedingly simple matter needing only a small and short screwdriver by means of which the screw fixing the dial drum to the condenser spindle can be loosened. A station is critically tuned, and then, after loosening the screw, the dial is rotated in either direction until the desired setting is reached.

Pointer Type Scale

The scale on the Ultra Panther receivers is of the light pointer type, and the carriage holding the two lamps can be moved without altering the tuning control by first taking off the scale and escutcheon, and then loosening the screw immediately behind the light carriage. Should the cord actuating this light pointer be detached, it is necessary to remove the chassis from its cabinet in order to refit it to the driving drum, as shown in the accompanying illustrations.

RADIO GRAMOPHONES

Both Ultra Tiger and Panther Receivers are available in the form of Radio Gramophones. In general layout they do not differ from the consolette models, but an electric motor is accommodated in the cabinet top and is covered by a shallow lid. The pickup is carried in a bakelite moulded tone arm, which is curved to set the needle bar at the best possible angle for tracking. This very important feature has been carefully worked out and gives a surprisingly accurate result over the whole of the playing area of a 12-inch record.

A slight modification is made in the chassis for the R.G. model, a double-volume control being substituted for the single control with switch; the latter being replaced by a toggle switch fitted through the cabinet side.

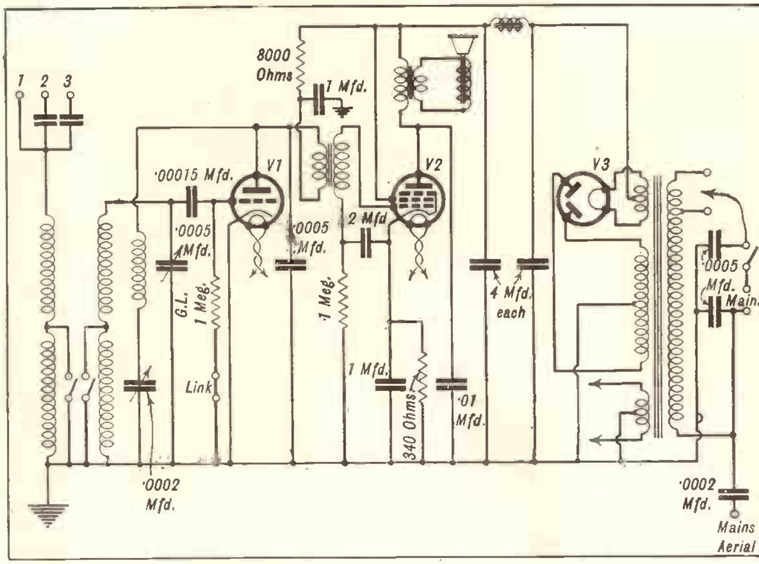


Fig. 19.—THEORETICAL CIRCUIT DIAGRAM OF ULTRA BLUE FOX A.C. RECEIVER.

the disconnection of the flexible leads feeding the gramophone motor. A glance will show that these are attached by means of a two-way connecting block so placed that either motor board or chassis is equally easy to take out should the necessity arise.

Motors

A.C. Models are fitted with induction motors designed to work on 40–50 cycle or 50–60 cycle mains. They are self-starting when used on the frequency for which they are designed, and apart from an occasional application of oil need no attention whatever.

An automatic stop is incorporated in each motor, and is an ingenious mechanism which insures satisfactory stopping on any record having the usual spiral cut-off groove. No individual setting is needed, the stop being adjusted before leaving the factory. Should it ever get out of adjustment it can be corrected by removing the turntable and adjusting the link mechanism as indicated in the instruction diagram supplied.

Removing R.G. Chassis

This process is almost identical with the table and consolette models, the only difference is in the removal of the "on" and "off" switch, this being held in position by a screwed ring, and in

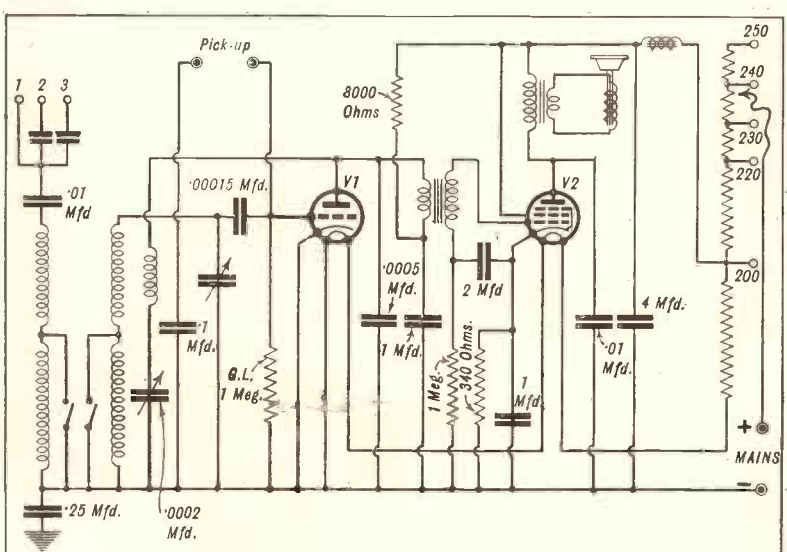


Fig. 20.—THEORETICAL CIRCUIT DIAGRAM OF ULTRA BLUE FOX D.C. RECEIVER

VALVE COUPLING SYSTEMS

By EDWARD W. HOBBS, A.I.N.A.

PRESENT-DAY wireless receiving sets consist of two or more valves electrically connected to one another by coils, transformers or other devices; such components with their associated circuit constitute a coupling system.

Additionally, the first valve is connected to the aerial by an input coupling system; the last valve is coupled by an output system to the loud speaker.

Coupling Systems Govern Circuit Design

Designing a receiving set really means the selection of suitable valves, and the choice and use of the most appropriate coupling systems; conversely, a critical examination of a receiver circuit is more readily achieved by dividing it into its individual coupling systems and considering them separately.

Conveniently the coupling systems can be divided into five groups, viz., aerial input, high-frequency couplings, detector circuits, low-frequency couplings, and output couplings.

Basic Conceptions

Much confusion of thought will be avoided if a few basic principles or facts be thoroughly understood, so that an accurate—although not necessarily scientifically expressed—conception of the working of a receiver can be obtained.

What Really Happens

Take as an example a simple three-valve set with one H.F. valve, a detector, and one L.F. valve, such as that of Fig. 1; this includes one of each of the five coupling systems.

The aerial picks up every signal that is being transmitted at any given time, and the first coupling—the aerial-input system, A in Fig. 2—picks out the required signal and delivers it in proper form to the grid of the first valve which amplifies it and by means of the second or H.F. coupling system (B of Fig. 2) delivers it at enhanced strength to the detector valve. This valve by virtue of its design and aided by the detector circuit (C, Fig. 2) "rectifies" the signal, which up to this stage is of too high a frequency to actuate a pair of headphones or a loud speaker.

The essential function of the detector circuit is therefore to change the signal or electrical current flow in such a way that it can actuate a loud speaker or other device which will emit audible notes and speech.

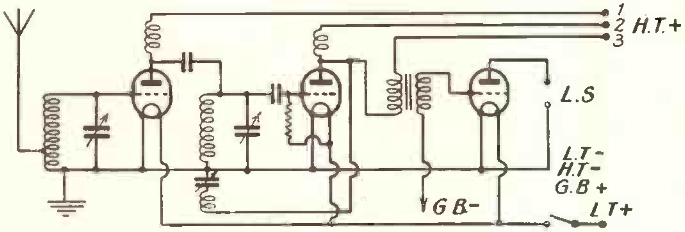


Fig. 1.—The Parent Circuit.

This shows the usual manner of presenting a theoretical circuit. The method of dividing the circuit into its various coupling elements or groups and of splitting it up into the H.F., L.F. and filament circuits is shown in Figs. 2–5.

The fourth, or low-frequency coupling system (D of Fig. 2) amplifies the rectified currents and delivers them to the output valve which further strengthens them; the last coupling system (E in Fig. 2) links the output valve to the speaker and often includes devices to correct the tone or vary the volume of sound.

Choice of Valves

The valves may be chosen first and the coupling systems adapted to them, or the opposite course be adopted, but in either

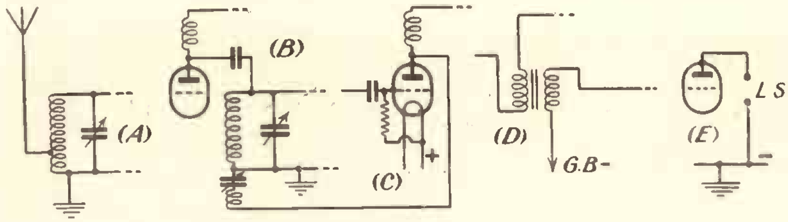


Fig. 2.—THE COUPLING SYSTEMS SEPARATED.

Here the five coupling systems are separated.

case it is essential that the characteristics of the valves and the electrical values of the coupling systems be in harmony, as will be explained later, meanwhile it is assumed that this is the case.

Apart from superheterodyne receivers and one or two others—which are dealt with elsewhere in COMPLETE WIRELESS—a

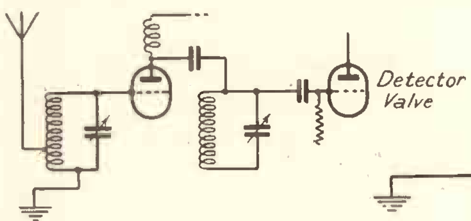


Fig. 3.—THE HIGH-FREQUENCY CIRCUIT.

High frequencies pass through this part of the circuit.

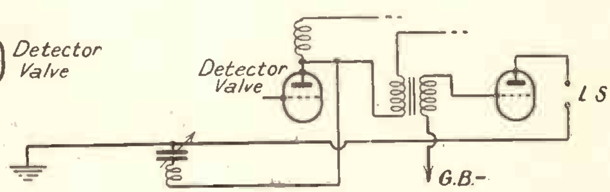


Fig. 4.—THE LOW-FREQUENCY CIRCUIT.

Modulated or audible-frequency currents flow in this part of the circuit.

valve is used to do one of three things: it can be used to amplify a high-frequency signal prior to detection, this circuit is shown in Fig. 3; it can "detect" a signal, or it can amplify a low-frequency signal, the circuit being shown in Fig. 4.

The filament heating circuit (Fig. 5) has simply to heat the filaments and acts as a common earth return.

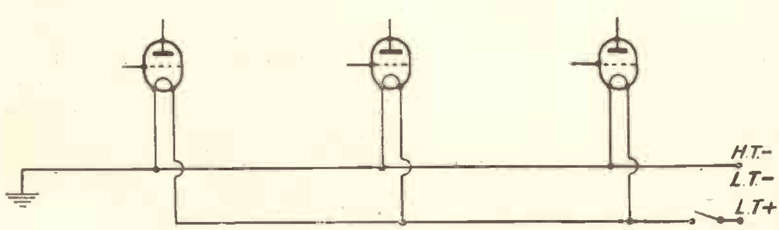


Fig. 5.—THE FILAMENT CIRCUIT.

Above is shown the filament heating circuit and the common negative or earth return lead.

First Coupling System

Bearing this orderly progression of functions in mind, detailed consideration can now be given to the essentials of each group commencing with the aerial input coupling system—or the aerial tuning circuit, as it is often called.

The ability of an aerial tuning system to pick out a particular signal depends upon the correct use of "inductance"—that is, a coil of wire—and "capacity"—that is, a condenser.

How these devices work is explained fully elsewhere in COMPLETE WIRELESS, suffice it to say here that there is a definite value of inductance (abbreviated L) and capacity (abbreviated C) which can be considered as offering no opposition to one particular frequency and at the same time providing considerable opposition to all other frequencies.

Carrier Wave

Every wireless signal is transmitted by means of an alternating current having a definite unchanging frequency called the carrier wave. All European transmission frequencies

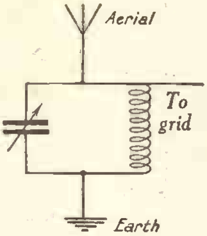


Fig. 6.—HEAVILY DAMPED CIRCUIT.

Tuning is very broad because of the sluggishness of the aerial and earth leads.

are separated by at least 9,000 cycles (9 kilocycles); for example, London Regional transmits on 355·9 metres, that is, 843 kilocycles per second; Stuttgart on 60·63 metres, that is, 832 kilocycles; and Graz on 352·1 metres, that is, 852 kilocycles.

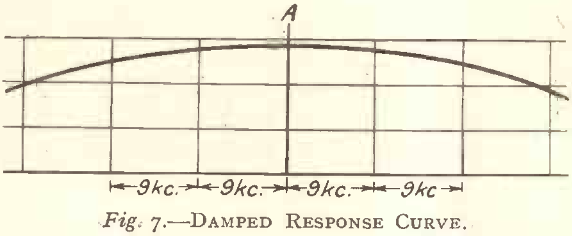


Fig. 7.—DAMPED RESPONSE CURVE.

The curve represents the apparent audibility of signals persisting over a wide frequency range.

Modulation

Carrier waves are inaudible to the human ear, and cannot actuate a loud speaker direct. What actually operates the loud speaker is the low or audible frequencies called the modulation, which are imposed on the carrier wave.

The modulation frequency can be likened to the jockey, the carrier wave to his horse. The horse and the carrier wave can both travel alone, neither can emit understandable speech, but by impressing audible frequencies on the carrier wave, as by mounting the jockey on the horse, the means of speech are transmitted from place to place.

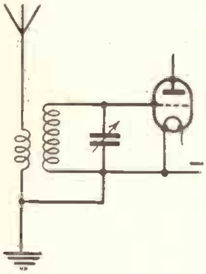


Fig. 8. — LIGHTLY DAMPED CIRCUIT.

Damping is reduced by separating the grid coil and coupling the aerial loosely to it.

Audible Frequencies

The human ear responds only to sounds having a frequency of roughly about 30 to 10,000 cycles. The B.B.C. transmissions cover all speech and music frequencies from 30 to 8,000 cycles, equivalent to the complete range of musical notes with their correct overtones.

These sounds, emitted primarily by the performers at the transmitting station, are converted into electrical current impulses of the same frequencies and impressed on the carrier wave; ultimately they reappear in the form of sound waves from the loud speaker.

It is most important to grasp these facts because the coupling systems have to be so devised that they can handle all these subtle variations of low-frequency current superposed on a carrier wave of much higher frequency.

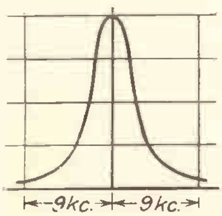


Fig. 9. — RESPONSE CURVE OF HIGHLY DAMPED CIRCUITS.

Here the response is limited to a very narrow band, side-band cutting and loss of quality would be inevitable.

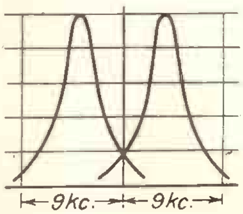


Fig. 10. — RESPONSE CURVES OF TWO TUNED CIRCUITS.

When two circuits are tuned and react on each other two peaks are formed equally spaced on each side of the carrier frequency.

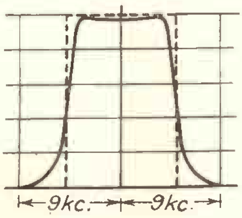


Fig. 11.—IDEAL TUNING RESPONSE CURVE.

The absolute ideal is a rectangle as shown dotted, but the practical realisable ideal has the peaks flattened out to a substantially flat top and straight sides.

Ideal Tuning Systems

The ideal aerial tuning system should respond equally to all changes in the carrier wave, or, expressed in another form, the response curve should be flat over a frequency band of 8,000 to

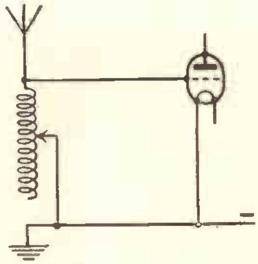


Fig. 12. — LODGE'S VARIABLE INDUCTANCE.
The original invention of Sir Oliver Lodge in 1895, it consisted of a sliding contact movable over a bared path on the coil.

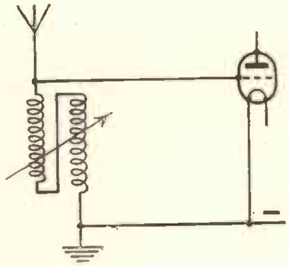


Fig. 13.—VARIABLE LOOSE COUPLER.
One part of the inductance is wound on a tube while the other part, wound on a larger tube, can be moved over it.

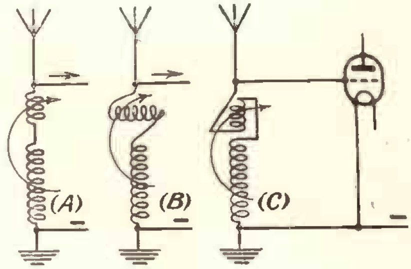


Fig. 14.—THREE POSITIONS OF A VARIOMETER
Winding the coil so that one part can turn within the other provides for tuning because the inductance is cumulative at A, neutral at B, and diminished at C.

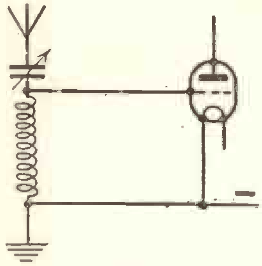


Fig. 15.—CAPACITY AND INDUCTANCE IN SERIES.
Broad tuning results.

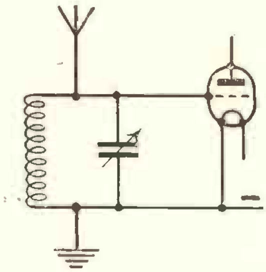


Fig. 16.—INDUCTANCE AND CAPACITY IN PARALLEL.
Tuning still broad.

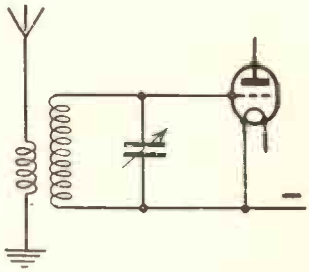


Fig. 17.—LOOSE COUPLED AERIAL.
Fairly sharp tuning, but tending to instability.

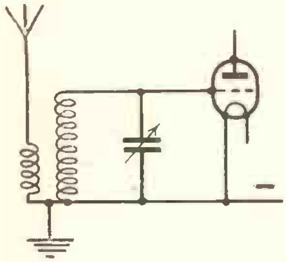


Fig. 18.—APERIODIC AERIAL COUPLING.
A scheme giving fairly sharp tuning.

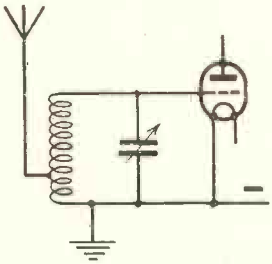


Fig. 19.—AUTO-TRANSFORMER COUPLING.
Sharp tuning results.

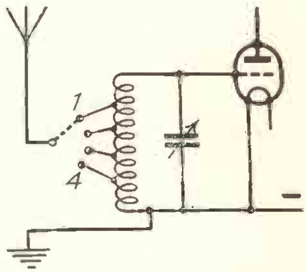


Fig. 20.—OPTIONAL AERIAL TAPPINGS.
Sharpest at 4 and broadest at 1.

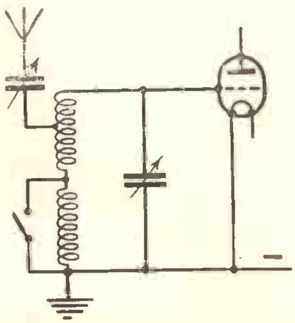


Fig. 21.—DUAL RANGE COIL.
Two windings in series, with a switch to short-circuit the lower- or long-wave winding. Tunes sharply.

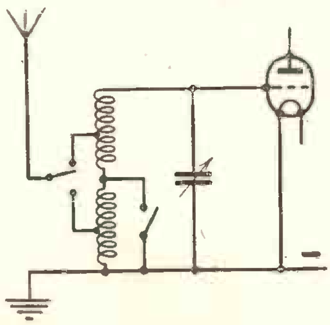


Fig. 22.—CHANGE-OVER AERIAL COIL.
A dual range coil switched so that equal proportions of inductance are used in either the medium- or long-wave range.

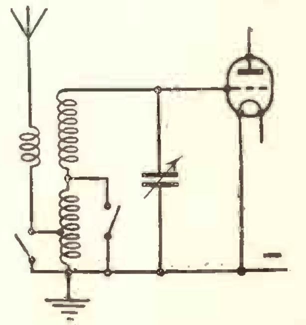


Fig. 23.—UNIFORM CAPACITY TRANSFER SWITCHING.
Medium wave coil is magnetically coupled to aerial; long-wave coil is auto-transformer fed.

AERIAL COUPLINGS

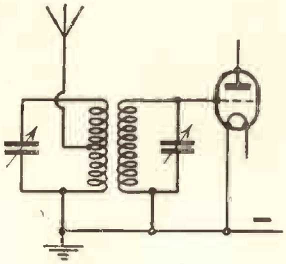


Fig. 24.—INPUT BAND-PASS FILTER.
The aerial is taken to centre of primary coil which is inductively coupled to the grid coil, both being tuned.

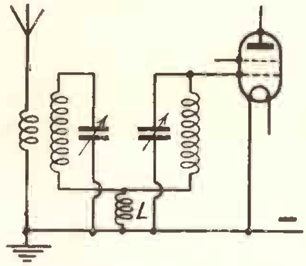


Fig. 25.—INPUT FILTER CIRCUIT.
A very selective filter circuit, the tuned coils being coupled by the small inductance L. Various response characteristics are possible.

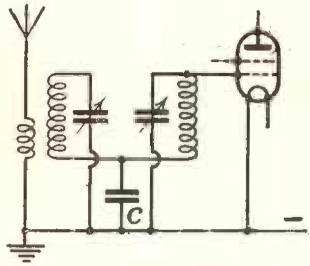


Fig. 26.—BAND-PASS COUPLING.
An effective system combining quality with reasonable selectivity. The coupling condenser C may have a value of about ·01 mfd. Dual range is by switching.

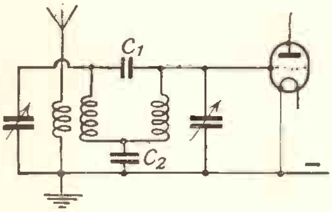


Fig. 27.—CONSTANT WIDTH TUNER.
By suitably adjusting the values of coupling condensers C1 and C2, and the coupling between aerial and first filter coil, a constant width response is obtained.

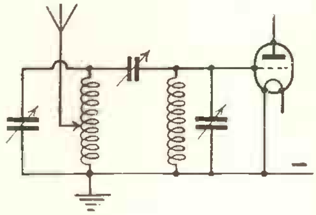


Fig. 28.—GANGED CAPACITY COUPLING.
The three variable condensers are ganged, and a constant width of response is obtained by suitably adjusting their initial values.

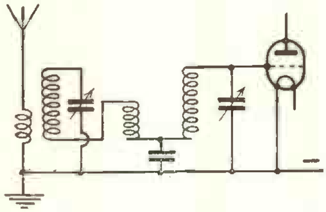


Fig. 29.—CONSTANT WIDTH INPUT FILTER.
Gives a constant breadth of response to the modulated frequencies.

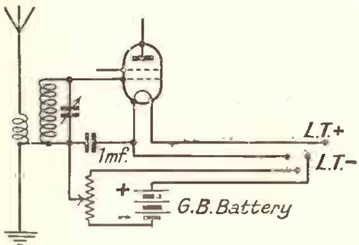


Fig. 30.—VARIABLE-MU VALVE.
Control of volume when a variable-mu valve is used can be effected by a potentiometer across the G.B. battery, separately switched to prevent current flow when the set is not playing.

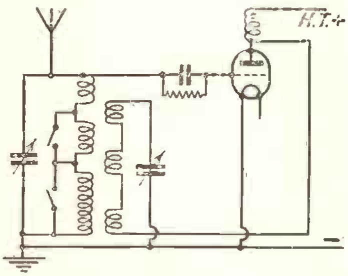


Fig. 31.—TRIPLE RANGE AND REACTION.
An arrangement enabling reception on short, medium or long waves. Three separate reaction windings in series ensure smooth control.

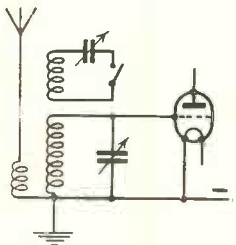


Fig. 32.—ABSORPTION WAVETRAP.
A means of reducing local station interference. The wavetrap when tuned to the unwanted frequency, virtually absorbs and obliterates the magnetic field of the aerial coil.

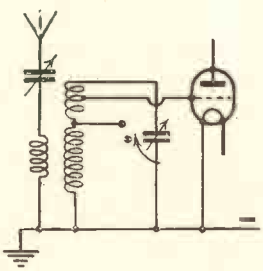


Fig. 33.—EXTENSOR TUNING.
Dual wave range control without separate switching is obtainable with an "extensor" variable condenser

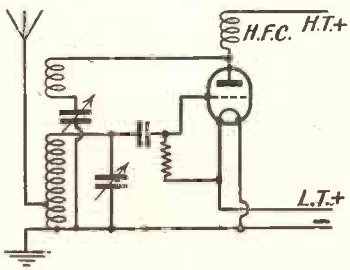


Fig. 34.—CAPACITY REACTION.
Reaction is applied by a condenser of average value ·0003 mfd. between reaction winding and earth.

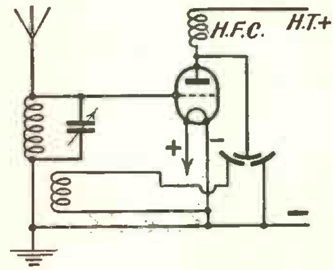


Fig. 35.—DIFFERENTIAL REACTION.
A development of capacity reaction, the control is finer and the valve more stable.

10,000 cycles per second on each side of the carrier frequency.

To prevent interference from other stations there should be no response outside this frequency band, but as carrier waves are separated only by 9,000 cycles it follows that if interference is to be entirely eliminated there will in most cases be some side band cutting; this means that some of the modulation current will be either cut out altogether, will be severely reduced in strength, or will be distorted.

It would seem to be impossible to receive pure undistorted music without interference, and this is in many cases true, but any listener within the service range of a modern British transmitting station can obtain a quality of reproduction which is undistinguishable from the original.

Designing for Quality

Assuming that the highest musical quality is the object aimed at, then the factors to consider in the design or selection of the aerial-input and H.F. coupling systems are: locality of the receiver and percentage of modulation or width of modulation frequency band.

These factors determine which of the various stations can be received with sufficient strength and separation width to allow the use of a tuning system with sufficient "flat top" to ensure linear reception of the modulation frequency band.

Getting the Stations

If the principal object is reception from as many different stations as possible, it is obvious that quality will have to be sacrificed to some extent in the first and second coupling groups to ensure sufficiently "sharp" tuning to give interference free reception with 9 kilocycle separation.

A general purpose set is a compromise between the two, giving reasonable quality from the local or very powerful stations and sufficient selectivity to give passable reception from a considerable number of stations.

Practical Circuit Design

A number of practical circuits for aerial-input coupling systems are illustrated in Figs. 12 to 47, with the salient features of each described in the captions beneath each illustration.

Similar methods are followed with the other four groups of coupling systems, *hence complete circuits for straight receivers of any type or purpose can be obtained by selecting the couplings most suitable to the purpose and connecting them with the appropriate valves.* For clarity the circuits shown are adapted for battery-operated sets, but when mains units are desired it is generally only necessary to treat the cathode of an A.C. valve as the filament of a battery valve and to add the simple filament heating circuit. Some special points to be considered with various mains sets are, however, specifically described.

Damped Circuits

It is not much use studying a number of circuit diagrams unless their purpose or meaning is understood. To begin at the beginning, a broad or heavily damped tuning circuit is one in which the waves gradually die away, or more easily thought of as one which cannot respond quickly to small changes in value of inductance or capacity, for example, in Fig. 6, a plain coil and a common variable condenser are shown in the aerial-earth circuit, this would tune broadly because of the impossibility of electrically adjusting the aerial and earth leads.

Comparisons of tuning systems are best studied by a graph or chart such as that of Fig. 7, where the vertical lines represent 9 kilocycle carrier wave separations. The curve is the apparent audibility of the signal, tuned to a maximum at A, and slowly falling off on each side, the condenser would have to be tuned by an amount corresponding to 50 or 60 kilocycles before the signal is lost.

Undamped Circuits

If the aerial and earth damping is taken out of the circuit, as, for example, by making a loose coupling between it and the tuning coil as in Fig. 8, then the tuning becomes much sharper, as in Fig. 9,

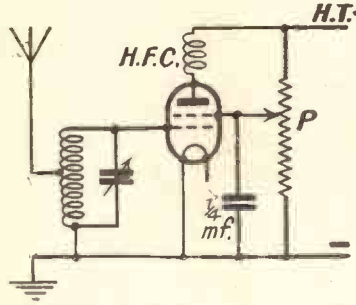


Fig. 36.—Control of Volume.
Control of output from a screen-grid H.F. valve can be effected as above.

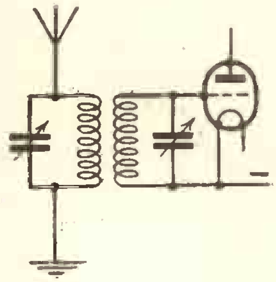


Fig. 37.—Tuned Transformer Coupling.
The incoming signal is tuned by the aerial coil and condenser.

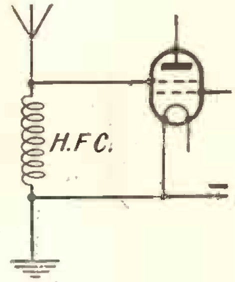


Fig. 38.—Choke Coupling.
A useful arrangement for short wave work, a S.W. high-frequency choke takes the place of the usual aerial coil.

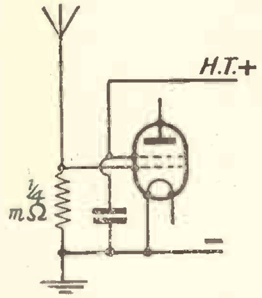


Fig. 39.—Resistance Coupling.
Another short-wave aerial coupling, a signal voltage is developed across the resistance, amplified by the valve and tuned in a second coupling stage.

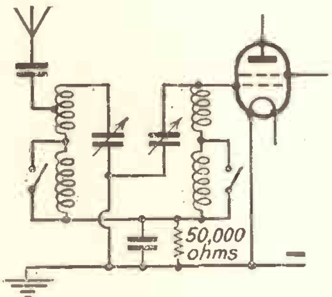


Fig. 40.—Dual Range Band-Pass Filter.
Two dual range tuning coils, tuned by a ganged condenser and coupled by a fixed condenser.

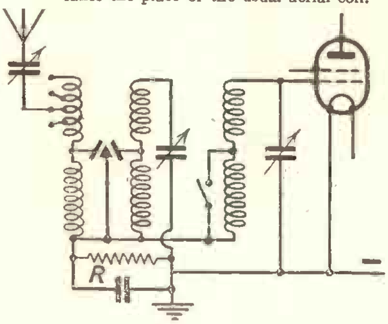


Fig. 41.—Coupled Primary Band-Pass Tuning.
The addition of a third coil magnetically coupled to the first filter coil, and all three resistance-capacity coupled.

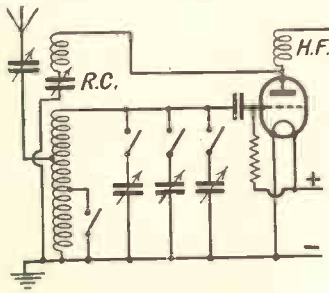


Fig. 42.—Pre-set Tuner.
Three separately switched pre-set tuning circuits are shunted across the aerial tuning inductance, the latter having dual-range coils and an anti-break through device. See p. 117.

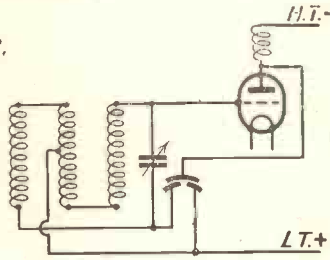


Fig. 43.—Dual Range Frame Aerial Tuning.
A suitably wound frame aerial can be used as a tuning inductance, the middle winding is centre tapped, the two outer windings are switched in series with it for long-wave reception.

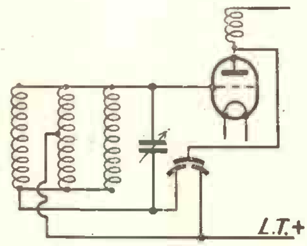


Fig. 44.—Frame Aerial Switched for Medium Waves.
The three coils are switched in parallel for medium-wave reception. About 75 feet of wire for tapped centre winding and 250 feet for the two outer windings is generally correct.

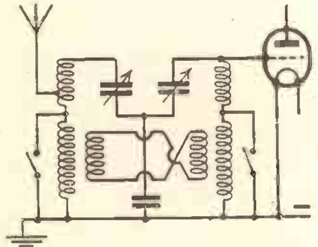


Fig. 45.—Band-Pass Link Filter.
Two dual range coils are coupled by the closed circuit linking coils. This gives excellent selectivity with characteristic band-pass flat top response.

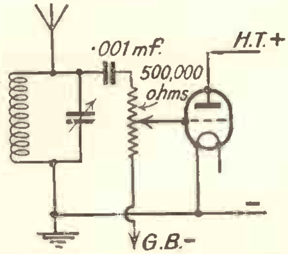


Fig. 46.—Input Volume Control.
The regulation of volume is here carried out by a coupling condenser and variable resistance arranged to feed the grid of the first valve.

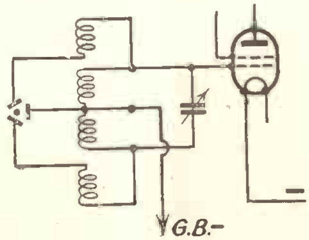


Fig. 47.—Dual Range Frame Aerial Switching.
The three-point switch when open leaves the medium-wave winding only in circuit.

HIGH-FREQUENCY COUPLINGS

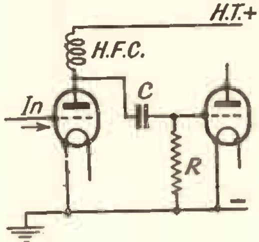


Fig. 48.—Choke Capacity Coupling.

The impedance of the choke builds up the signal which is handed on to the grid of the second valve *viâ* the condenser C. The grid leak R prevents unwanted grid currents. Average values, choke 25 to 50 henries, C ·0002, R 1 megohm.

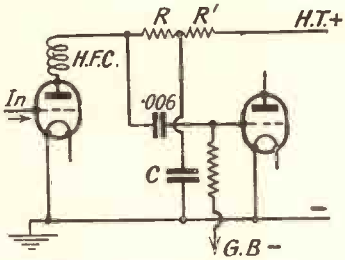


Fig. 49.—Resistance Capacity Coupling.

The anode resistance R should be about four times the impedance of the valve, the decoupling resistance R[1] may be about 25,000 ohms when C is 2 mfd.

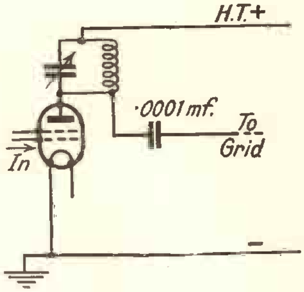


Fig. 50.—Tuned Anode Coupling.

A tuned inductance in the anode circuit forms an oscillatory circuit, and when tuned to frequency of signals causes a rejector action. Unstable unless used with a S.G. valve.

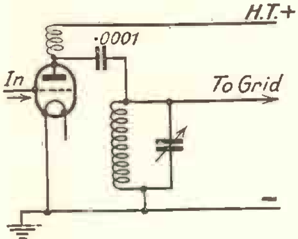


Fig. 51.—Tuned Grid Coupling.

A tuned inductance, fed from the first valve, shunted across grid and earth of second valve. Usually the coil and condenser should be matched exactly with those in the aerial coupling system.

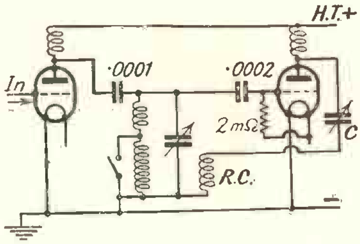


Fig. 52.—Dual Range Tuned Grid with Reaction.

By switching the inductance in a manner corresponding to that of the aerial circuit, dual range working is obtained.

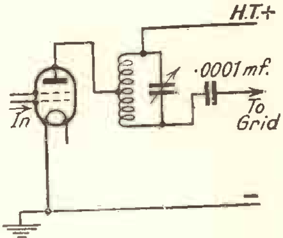


Fig. 53.—Tapped Tuned Anode.

A stage gain ratio of 2 to 1 is obtained by centre tapping the anode coil, greater selectivity and less volume is obtained by a 3 to 1 tapping.

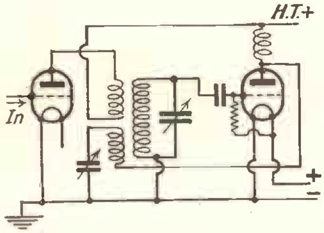


Fig. 54.—Tuned Transformer with Reaction.

Sharp tuning with a varying response width controlled by modifying the coupling between primary and tuned secondary windings.

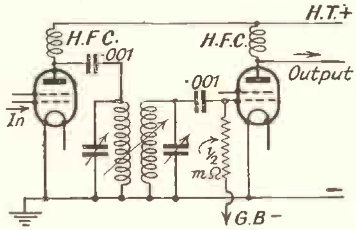


Fig. 55.—Magnetic Loose Coupling with Dual Tuned Circuits.

Very selective and sharp tuning, needs adequate de-coupling. Can be used for dual range when suitably switched.

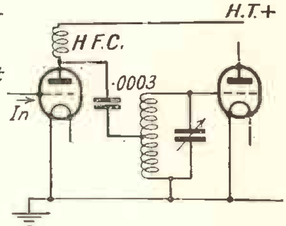


Fig. 56.—Tapped Tuned Grid Coupling.

A step-up voltage is obtained by the centre tap. A stable and fairly sharp tuning arrangement, with good quality.

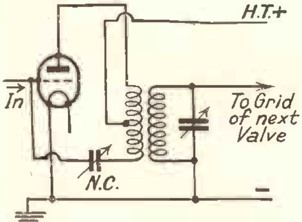


Fig. 57.—Neutralised Transformer Coupling.

A tapped primary magnetically coupled to a tuned secondary coil ensures selectivity of a high order with fairly good quality.

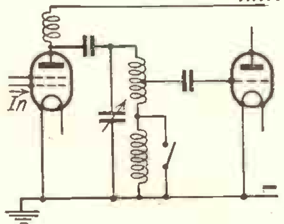


Fig. 58.—Dual Range Tapped Tuned Grid Coupling.

Dual wavelength tuning by short-circuiting the long-wave winding by a simple switch. For use in conjunction with single tuned aerial couplings.

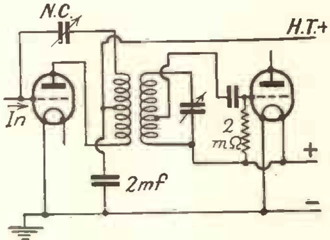


Fig. 59.—Neutralised Centre Tapped Transformer Coupling.

Stability is obtained by the low value condenser N.C., and by the de-coupling or by-pass condenser.

DETECTOR CIRCUITS

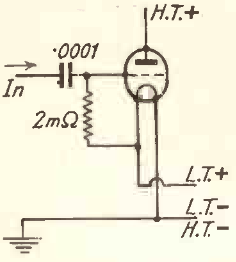


Fig. 60.—LEAKY GRID DETECTOR.
Rectification is obtained by using the grid current flow, the grid is negatively charged from the grid condenser and reduces the value of anode current.

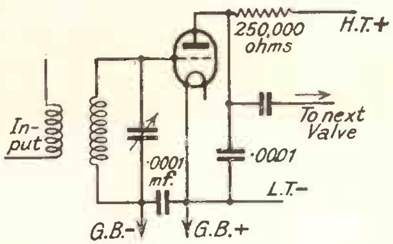


Fig. 61.—ANODE BEND DETECTOR.
In this system the curvature of the anode current grid volts characteristic of the valve is made use of. For details see articles on Valves.

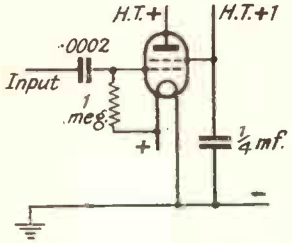


Fig. 62.—S.G. VALVE AS A DETECTOR.
A screen-grid valve can be used as a detector; it should be biassed or not in accordance with the operating data furnished with the specific valve.

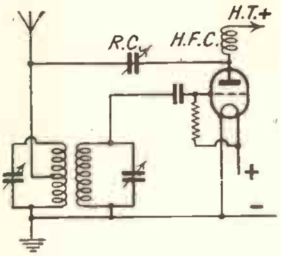


Fig. 63.—AERIAL AND REACTION COIL COMBINED.
By suitably tapping the aerial primary coil a portion of the windings can be used for reaction purposes; it is energised by a small variable condenser R.C. in the anode aerial circuit.

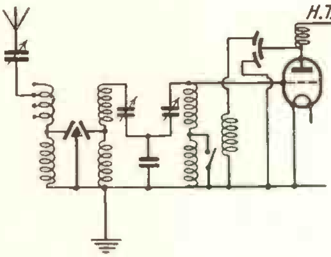


Fig. 64.—B.P. TUNING WITH REACTION.
When the first valve is the detector, a flat-topped response curve with good selectivity is obtained by an inductive aerial coupling to a band-pass filter.

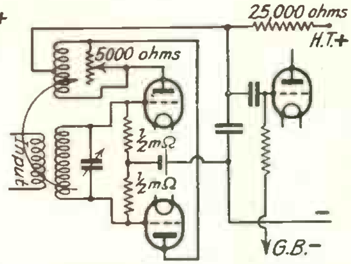


Fig. 65.—PUSH-PULL DETECTOR.
A method of rectification which uses both halves of the signal current; it can be used when following a H.F. stage or when the detectors are the first valves.
Notable for purity of reproduction.

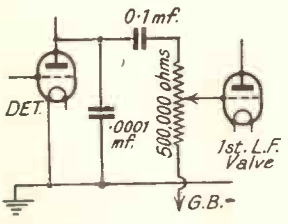


Fig. 66.—VOLUME CONTROL OF FIRST L.F. VALVE.
When following a detector, the volume delivered by the set can be controlled by a capacity and 500,000 ohm potentiometer as shown.

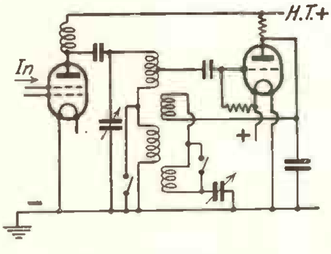


Fig. 67.—DUAL REACTION.
Separate reaction on each of the coil windings, with switching in the grid and reaction coils of a dual range tuner. Can be used in intervalve couplings or when preceding a detector valve.

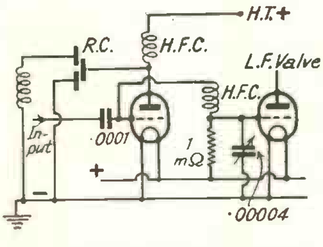


Fig. 68.—DIODE RECTIFICATION.
A valve used only for rectification; the valve does not amplify the signal. A very low voltage of 10 to 12 volts on the anode is sufficient to provide current for reaction purposes.

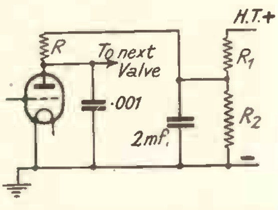


Fig. 69.—DECOUPLING AN ANODE BEND DETECTOR.
Adequate decoupling is always desirable in any circuit. The values here may be as follows: R, ½ megohm; R1, 50,000 ohms; R2, 100,000 ohms when H.T. current is 200 volts.

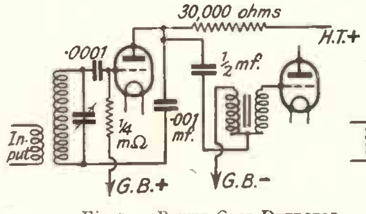


Fig. 70.—POWER GRID DETECTOR.
Above is the usual circuit when the detector is followed by a shunt fed transformer. The values given above are suited to a 2-volt valve with an impedance of 10,000 ohms. Grid bias, 4½ volts when anode H.T. is 150 volts.

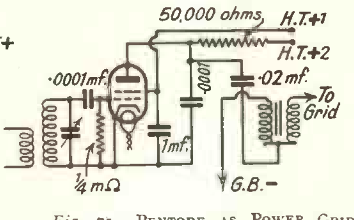


Fig. 71.—PENTODE AS POWER GRID DETECTOR.
Above is the circuit for a pentode detector in an A.C. mains set. Heater volts, 4. Anode voltage, 200 volts. Auxiliary grid, 150 volts. Values should be adjusted to suit the specific valves.

LOW-FREQUENCY AND TONE CORRECTION

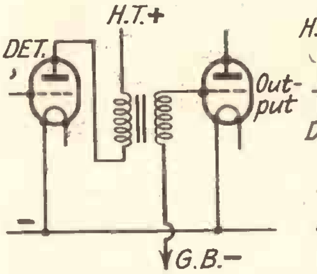


Fig. 72.—SIMPLE L.F. TRANSFORMER COUPLING.
Suitable for sets with anode currents not over 2 m.a.

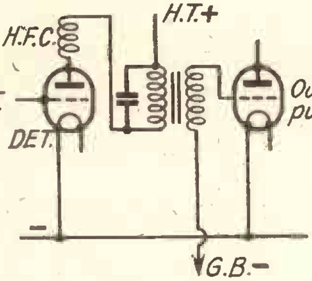


Fig. 73.—HIGH IMPEDANCE L.F. TRANSFORMER COUPLING.
A condenser about ·001 mfd. in value often improves the performance.

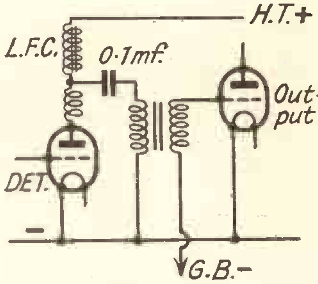


Fig. 74.—CHOKE CAPACITY L.F.T. COUPLING.
Preferable when anode current exceeds 2 m.a.

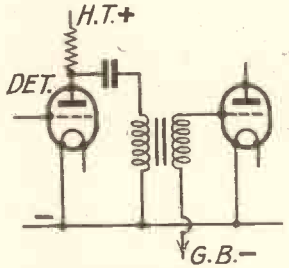


Fig. 75.—RESISTANCE FED TRANSFORMER.
Indirect feed by means of a resistance in the anode circuit and a coupling condenser.

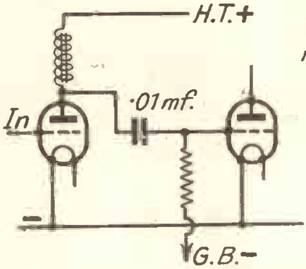


Fig. 76.—CHOKE CAPACITY COUPLING.
A value of 50 henries is suitable when current does not exceed 30 m.a.

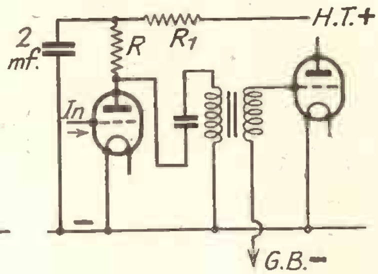


Fig. 77.—PARALLEL FEED L.F.T. WITH DE-COUPLING.
De-coupling is effected by a 1 mfd. condenser between R and R1. R1 is about 75,000 ohms. R may be 30,000 ohms.

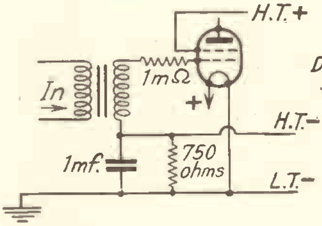


Fig. 78.—TRANSFORMER COUPLING WITH AUTOMATIC GRID BIAS.
Values given are suited to a battery valve with 120 volts H.T. current.

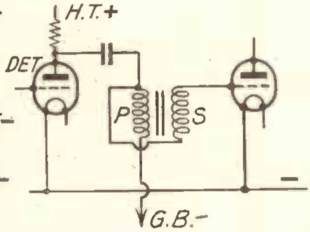


Fig. 79.—PARALLEL FEED AUTO-TRANSFORMER.
L.F. transformer performance is often improved by the above arrangement.

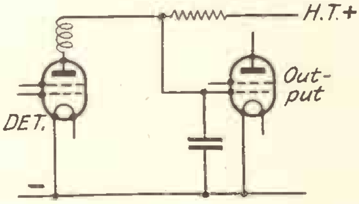


Fig. 80.—DIRECT L.F. COUPLING.
High impedance valves with relatively low H.T. voltages are used

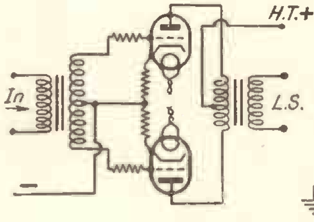


Fig. 81.—PUSH-PULL COUPLING.
The above shows the usual arrangement with A.C. valves. The grids of both valves are fed from the secondary of the input transformer, the anodes feed the primary of the output transformer. Pure and powerful reproduction.

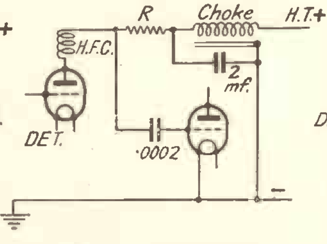


Fig. 82.—RESISTANCE IMPEDANCE COUPLING.
An intervalve coupling giving very pure distortionless amplification. With average battery valves the resistance R may be 50,000 ohms and the choke 50 henries.

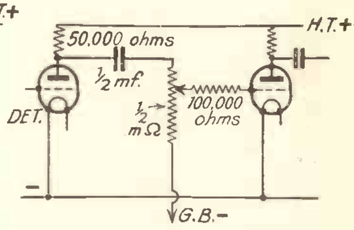


Fig. 83.—VARIABLE RESISTANCE-CAPACITY COUPLING.
Pure brilliant reproduction is obtained by this scheme, the values given are suited to average battery valves. Tone and volume can be varied by the 100,000 ohm potentiometer.

LOW-FREQUENCY AND TONE CORRECTION

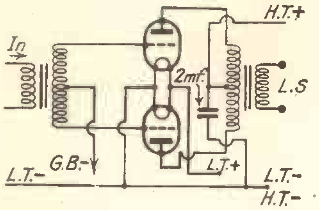


Fig. 84.—PUSH-PULL WITH BATTERY VALVES.

When greater volume is needed than obtainable from a power valve, the use of two arranged as above can be adopted. Reproduction is exceptionally clear, crisp, pure, and undistorted as the two valves are able to handle a large output. The grids are fed from the secondary of the input transformer and are biassed *viâ* the centre tapping. High tension current is fed to the centre tapping of the output primary and is de-coupled by a 2 mfd. or other suitable condenser. Suitable valves should have a low impedance, say, 1,500 ohms, and an optimum load of about 3,500 ohms.

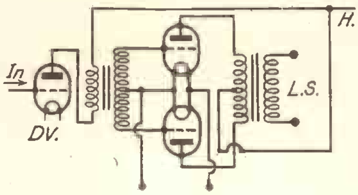


Fig. 85.—DRIVER VALVE AND P.P. AMPLIFIER.

Recent experiments point to the use of a driver valve to energise the primary of the input transformer, the secondary of which is used to feed the grids of the two push-pull valves. By suitably choosing the valve characteristics one push-pull valve works at full load for one impulse and then falls to zero while the other push-pull valve takes up the second impulse, this cycle being continued while the set is playing. By this means the whole of the straight part of the valve curve is used to amplify in one direction, each valve handling one direction of current swing only.

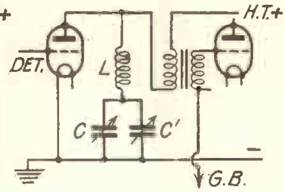


Fig. 86.—WHISTLE REDUCER.

Heterodyne whistles can often be removed from the L.F. stages of a receiver by inserting a suitable inductance L and capacities C into the circuit. The values must be chosen so that the circuit can be tuned to the frequency of the whistle, which is usually about 9,000 cycles per second. One condenser may be of fixed value, say, ·002 mfd. across a pre-set variable condenser of about ·001 mfd. capacity.

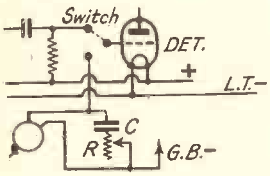


Fig. 87.—PICK-UP CIRCUIT.

Usually inserted in the input side of a detector valve. The switch enables the input from the tuning coil, or the lead from the pick-up to be connected at will to the grid of the detector.

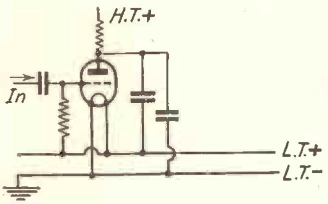


Fig. 88.—DETECTOR DECOUPLING.

Adequate de-coupling of the detector and L.F. valves improves performance and eliminates feed-back. One condenser shunted across anode and earth is supplemented by a smaller capacity across anode and L.T. + filament terminal.

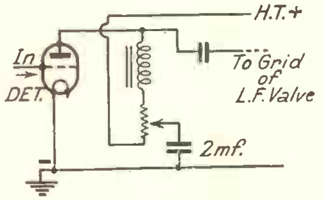


Fig. 89.—TONE CORRECTION CIRCUIT.

Tone can be varied and unequally amplified frequencies either built-up or subdued by inserting a ½ henry choke in series with a variable resistance in the H.T. anode circuit. The resistance has a capacity coupling to earth.

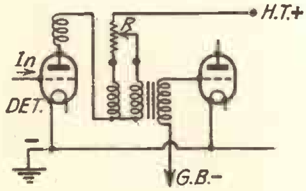


Fig. 90.—TONE COMPENSATING L.F. TRANSFORMER.

The proper balance of amplification can be restored in large measure by using a "split primary" L.F. transformer with a 5,000 ohm variable resistance shunted across the open ends of the primary windings.

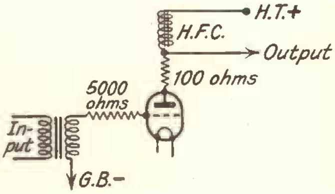


Fig. 91.—GRID AND ANODE STOPPERS.

Parasitic oscillation in L.F. stages can often be cured by the use of anode and grid stoppers as here shown; values given are an average, but must be suited to specific conditions.

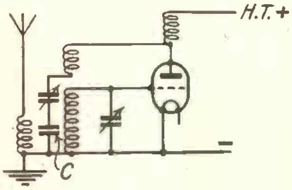


Fig. 92.—SAFETY CONDENSER.

A small value fixed condenser C in series with any variable condenser subjected to steady battery or H.T. current is an excellent safety precaution; it prevents a short circuit should the variable condenser blades touch the fixed blades or the frame.

because the condenser has only to adjust the values of the secondary circuit.

If two loose coupled circuits are separately tuned they react on each other and produce a double peaked curve, with the peaks on each side of the frequency to which the circuits are tuned, as in Fig. 10, the separation of the peaks being governed by the damping and the degree of coupling. If suitable inductance and capacity values are used the peaks can be flattened out into a sensibly flat-topped or ideal tuning curve, as in Fig. 11.

High-Frequency Coupling Systems

The number of H.F. stages should be governed by the detector valve, because it is useless applying to it a greater input voltage than it can handle without distortion. Generally one stage is sufficient; if more are used an efficient input volume control is necessary to cut down the signal strength from the powerful stations. Screen-grid and variable-mu valves are generally the best to use in H.F. stages; adequate screening and decoupling are necessary in most cases.

Decoupling is necessary to prevent feed back between anode and grid, and various methods are illustrated and described in these pages.

All the previous remarks on uniformity of amplification and breadth of response apply to tuned circuits in H.F. stages with equal importance. They must, however, be sufficiently damped to respond to all the rapid modulation changes in the carrier.

There are many systems of H.F. coupling, but those mostly in vogue are dealt with in Figs. 48 to 59 with the accompanying captions.

Detector Circuits

The functions of a detector valve are to reproduce without distortion the amplitude changes of the incoming carrier wave, to convert the A.C. current into unidirectional current carrying with it the audio-frequency modulations, and to amplify the rectified signals.

The usual method is the leaky grid or cumulative grid system, but anode bend detectors, as well as some others are occasionally used.

A good grid detector will give distortionless rectification of incoming carriers up to 80 per cent. modulation and up to 100 per cent. modulation with only inaudible distortion.

Grid leak values are determined by the resistance of the grid-filament path, and by the total capacity of grid-condenser and grid-filament capacity; the value of grid-leak resistance must be high at all amplitudes compared to that of the grid-filament path.

Various circuits and couplings are illustrated and described in Figs. 60 to 71, together with notes on appropriate values of components.

Low-Frequency Coupling Systems

The essential difference between a L.F. coupling system and the H.F. couplings is that the L.F. system has to amplify a modulated unidirectional current, whereas in H.F. coupling stages the current is a high-frequency A.C.

Various coupling systems for L.F. stages pick-up, tone and volume controls are described and illustrated in Figs. 72 to 92. The chief points to study are to avoid overloading the valves, otherwise audible distortion will occur because of partial rectification of the audio-frequency currents.

High anode voltages are desirable, and sufficiently high anode impedances to ensure linear amplification. Reference should be made to the various articles on valves and their working for an explanation of this part of the receiver design.

Anode Impedance

Any anode impedance should have a practically constant value for all frequencies up to 10,000 cycles per second, otherwise frequency distortion will occur.

Frequency distortion means that the impedance will over amplify, say, the high frequencies, and under amplify the low frequencies.

Transformers should have sufficient inductance to give adequate frequency response from about 50 cycles upwards.

The valves should be suited to the transformers, and if choke-capacity or resistance-capacity fed, the condenser should have such a value that resonance

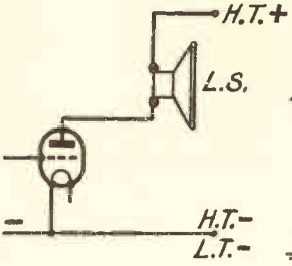


Fig. 93.—SIMPLE LOUD SPEAKER CIRCUIT.
This is the simplest circuit for low power battery sets, the loud speaker is directly in the H.T. + lead to the anode, The same circuit is used when the L.S. has a self-contained transformer.

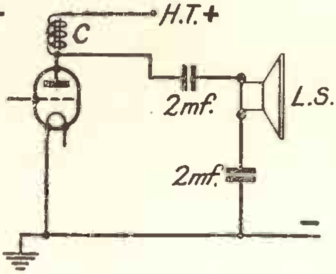


Fig. 94.—CHOKE CAPACITY CONNECTIONS.
Better reproduction is obtained by using a choke—about 30 henries—in the anode, H.T. + lead and feeding to the L.S. through a fixed condenser.

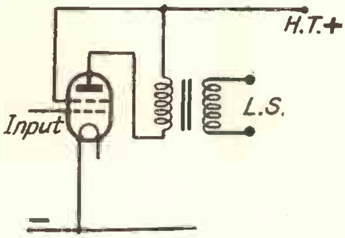


Fig. 95.—PENTODE WITH TRANSFORMER OUTPUT.
The values of the output transformer must be carefully matched to the impedance of the valve.

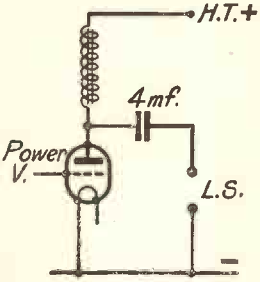


Fig. 96.—CHOKE CAPACITY OUTPUT.
A choke of 30 to 50 henries is suitable when current does not exceed 30 m.a.

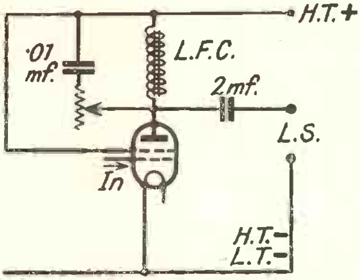


Fig. 97.—COMBINED CHOKE FEED AND TONE CONTROL FOR PENTODE.
The variable series resistance is from 25,000 ohms to 50,000 ohms value.

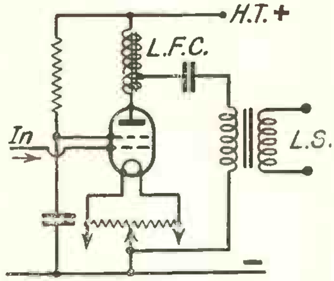


Fig. 98.—MOVING-COIL SPEAKER and PENTODE.
Circuit for a powerful A.C. mains pentode with parallel output transformer.

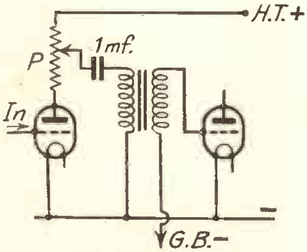


Fig. 99.—L.F. VOLUME CONTROL.
The potentiometer P with value 50,000 ohms when used with input valve has about 15,000 ohms impedance.

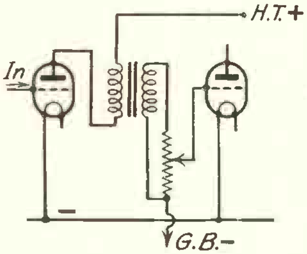


Fig. 100.—VOLUME CONTROL IN GRID CIRCUIT.
By regulating the potentiometer P.

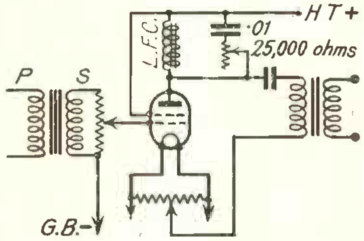


Fig. 101.—PENTODE WITH VOLUME AND TONE CONTROLS.

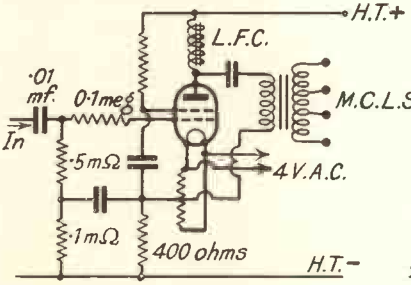


Fig. 102.—FULLY DECOUPLED PENTODE OUTPUT STAGE.
De-coupling by resistances in auxiliary grid circuit.

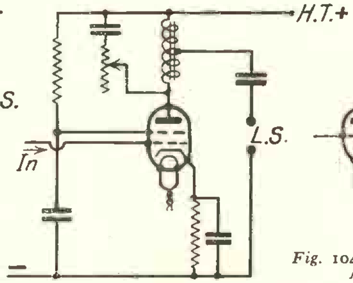


Fig. 103.—AUTO-TRANSFORMER AND TONE CONTROL.
Note that a capped choke is used in the anode circuit.

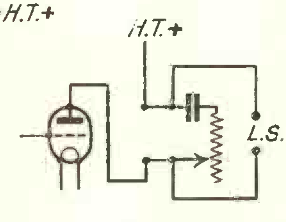


Fig. 104.—LOUD SPEAKER VOLUME AND TONE CONTROL.
A capacity of about ·01 mfd. in series with a 10,000 ohm variable resistance shunted across the output leads to a small loud speaker makes an efficient tone and volume control.

THE SUPERHETERODYNE

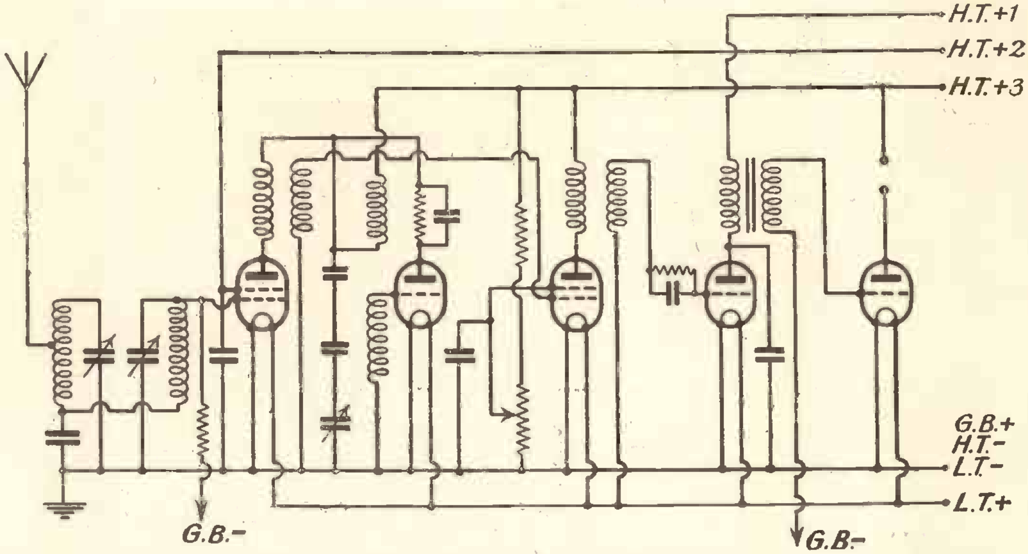


Fig. 105.—A TYPICAL FIVE-VALVE BATTERY SUPERHETERODYNE.

The superheterodyne circuit deserves very careful study; it is considered by many as the best type of receiver to meet modern conditions. Above is the circuit of a battery-operated five-valver.

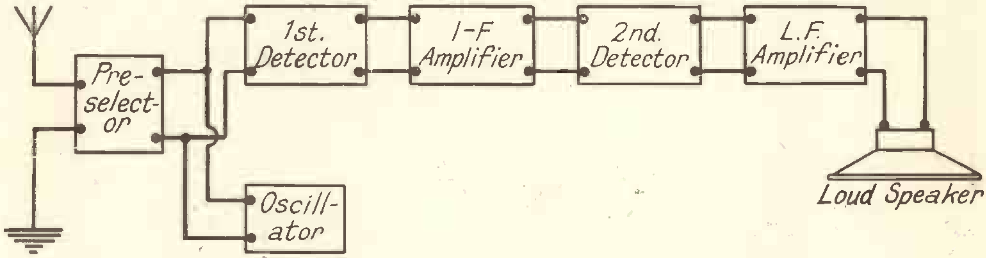


Fig. 106.—THE FUNDAMENTALS OF THE SUPER-HET ARE SHOWN IN THE ABOVE DIAGRAM.

The incoming signal is tuned in the pre-selector, which may include a H.F. amplifying stage and then applied to the first detector, The local oscillator supplies a current at any desired frequency to the first detector; this locally generated frequency is usually 110 kilocycles, and does not alter with alterations to the tuning of the pre-selector. The output from the first detector contains amongst others, the desired beat or mixed frequency which is selected and amplified in the first intermediate frequency (I.F.) amplifier. From here the signal is received by the second detector from which it appears as an ordinary modulated audio-frequency signal and is further amplified in the usual way by the output valve and delivered to the loud speaker.

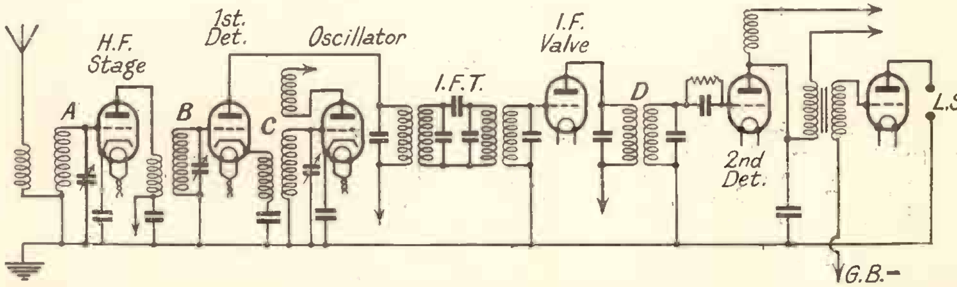
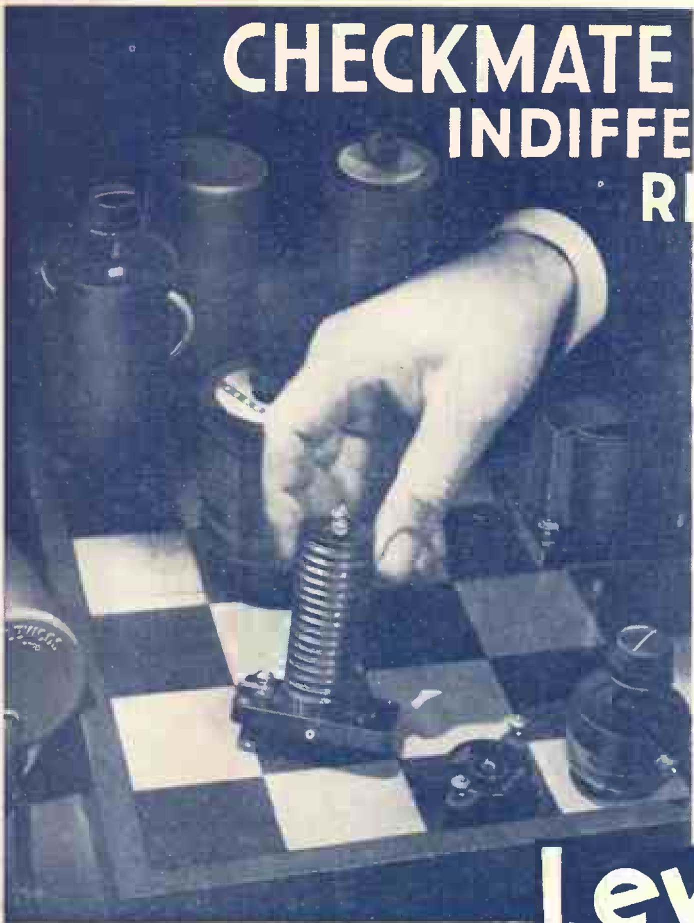


Fig. 107.—THIS SKELETON CIRCUIT SHOWS THE ESSENTIAL COMPONENTS AND THEIR ARRANGEMENT IN A SIX-VALVE RECEIVER.

Here A and B are the pre-selector tuned circuits. The oscillator coil C is coupled into the grid circuit of the first detector. A special intermediate filter on band-pass lines (I.F.T.) hands on the signals to the intermediate frequency valve (I.F.), whence they pass through the second filter D to the second detector, the remainder of the circuit then follows normal practice with straight receivers.

CHECKMATE INDIFFERENT RECEPTION



With

Lewcos

REGD

Radio Components

Descriptive leaflets of the components you need will be supplied on request to Radio Publicity Dept. N.

DESIGNED and constructed by experts using only the finest British materials, Lewcos Components are built to a standard by which all others are judged.

Distorted and indifferent reception and reproduction are unknown in receivers built with Lewcos Units.

Every type of Radio Component is made by Lewcos and stocked by all reputable dealers.

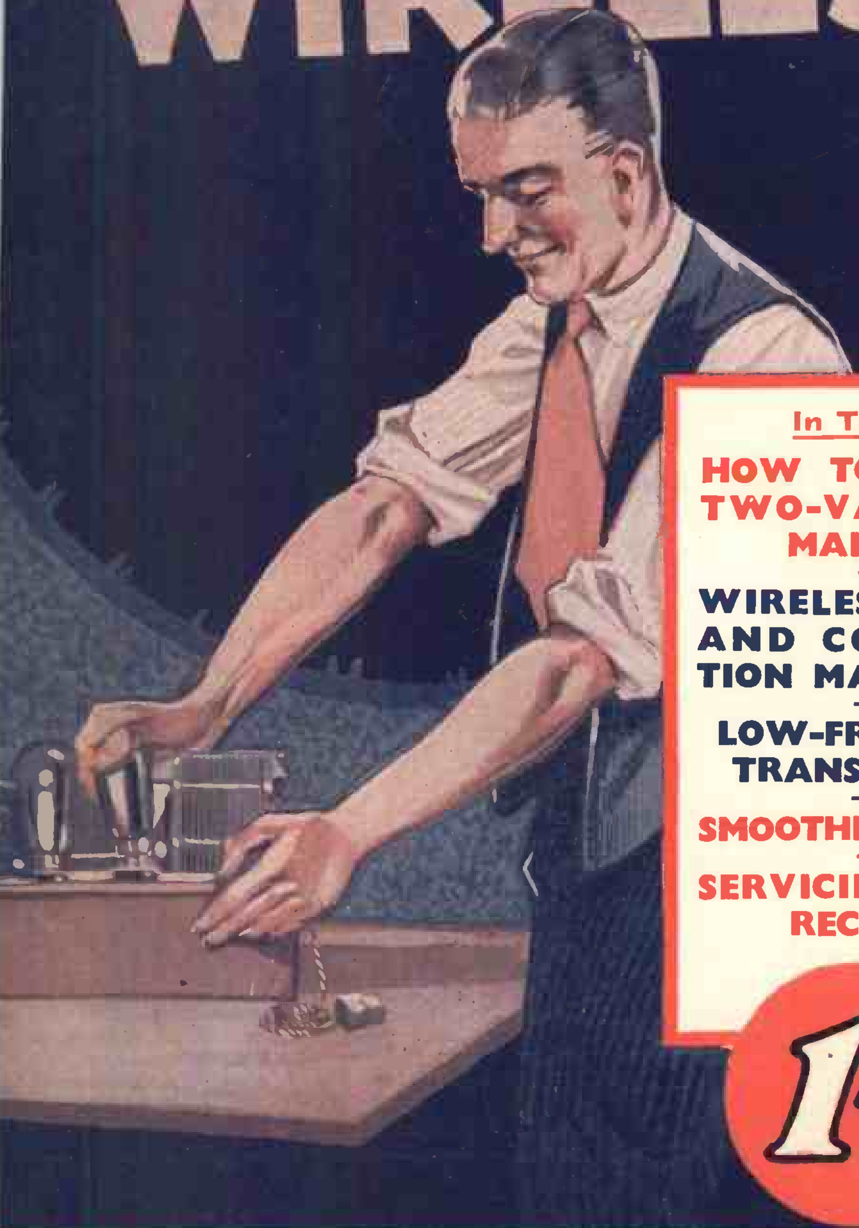
LEWCOS RADIO PRODUCTS FOR BETTER RECEPTION

THE LONDON ELECTRIC WIRE COMPANY AND SMITHS, LIMITED, CHURCH ROAD, LEYTON, LONDON, E.10

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australiasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS



In This Part

HOW TO MAKE A TWO-VALVE ALL-MAINS SET

WIRELESS THEORY AND CONSTRUCTION MADE PLAIN

LOW-FREQUENCY TRANSFORMERS

SMOOTHING CHOKES

SERVICING PHILCO RECEIVERS

1/-

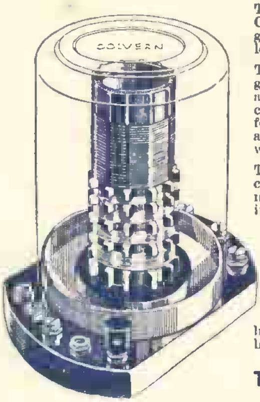
Part 18

IN ABOUT 24 WEEKLY PARTS

COLVERN

T.D. COIL

AN UP-TO-DATE COIL WITH UP-TO-DATE FEATURES



TYPE T.D., an entirely new COLVERN COIL, designed to give super selectivity on both long and broadcast wave-bands.

The coil is completely screened, giving a very neat appearance, and incorporates tapped aerial coupling and reaction, while the four alternative aerial tappings are arranged as sockets with a wander plug.

The first two tappings give aerial couplings similar to those normally employed but with greatly increased selectivity.

Nos. 4 and 5 give a high degree of selectivity with weak aerial coupling—suitable for use in a "swamp" area.

A most important feature of this coil is that there is no break through on the long waveband from B.B.C. stations.

TYPE T.D. - Price 8/6

Our 1933 Booklet Radio List No. 10 is now available and free on request.

COLVERN LIMITED

MAWNEYS RD. · · · ROMFORD, ESSEX

—and your batteries should be

Exide

AND

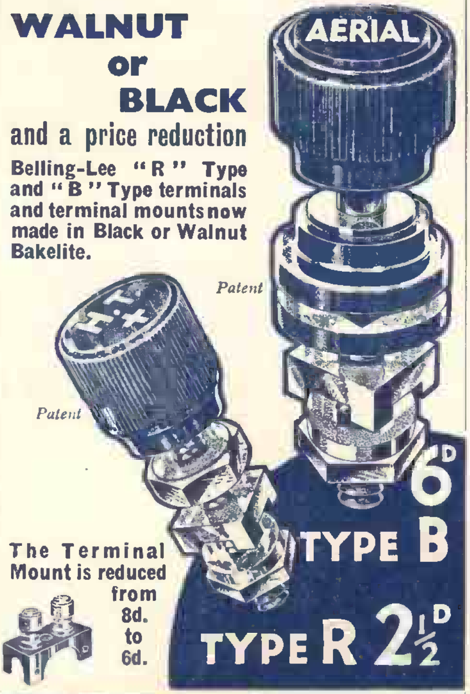
Drydex

There is a type for every set.

WALNUT or BLACK

and a price reduction

Belling-Lee "R" Type and "B" Type terminals and terminal mounts now made in Black or Walnut Bakelite.



The Terminal Mount is reduced from 8d. to 6d.

BELLING-LEE
FOR EVERY RADIO CONNECTION

Advert. of Belling & Lee Ltd., Cambridge Arterial Rd., Enfield, Middlesex.

UNITUNE

Gives extremely fine tuning, the trimmer of front section being operated independently from the panel by a knob concentric with the main tuning knob.

Rigid one-piece chassis, very robust construction. Trimmer to each stage.

Matched to within ½ mmfd. plus ½ per cent.

Complete with disc drive and bakelite escutcheon plate.

Capacity ·0005. 2 gang, 18/6; 3 gang, 27/-

JB PRECISION INSTRUMENTS

Advertisement of Jackson Bros. (London), Ltd., 72 St. Thomas' St., London, S.E.1. Telephone: Hop. 1837.

PART 18.

occurs at frequencies of 10 or less cycles per second.

Resistance-Capacity Coupling

In the case of resistance-capacity L.F. coupling the resistance values should be such that any stray capacities do not cause reduced amplification of the higher audible frequencies.

Conversely, the coupling condensers should be large enough compared to the grid leak resistance to prevent under amplification of low frequencies, otherwise tonal quality will be lost.

Adequate decoupling at every stage is most important, also the circuit of each coupling stage should confine the currents as closely as possible to the valves they serve.

Output Couplings

This group comprises various chokes, capacities and resistances used generally to control volume or tone or both. Examples with notes on their values are given in Figs. 93 to 104. In general, the important items are to match up the characteristics of the last valve, the loud speaker and the coupling system, and to take steps to ensure that the last valve has sufficient current handling power to deal with the maximum modulation signals without distortion.

The Superheterodyne

An outline analysis of the superheterodyne is given in Figs. 105 to 107.

The superheterodyne circuit deserves very careful study; it is considered by many as the best type of receiver to meet modern conditions.

Fundamentals of the Superhet

The incoming signal is tuned in the pre-selector (see Fig. 106), which may include a H.F. amplifying stage, and then applied to the first detector. The local oscillator supplies a current at any desired frequency to the first detector; this locally generated frequency is usually 110 kilocycles, and does not alter with alterations to the tuning of the pre-selector.

Output from First Detector

The output from the first detector contains, amongst others, the desired beat or mixed frequency which is selected and amplified in the first intermediate-frequency (I.F.) amplifier.

The Second Detector

From here the signal is received by the second detector from which it appears as an ordinary modulated audio-frequency signal and is further amplified in the usual way by the output valve and delivered to the loud speaker.

Skeleton Circuit of a Six-valve Superheterodyne

In the skeleton circuit of a six-valve superheterodyne (Fig. 107) A and B are the pre-selector tuned circuits. The oscillator coil C is coupled into the grid circuit of the first detector. A special intermediate filter on band-pass lines (I.F.T.) hands on the signals to the intermediate-frequency valve (I.F.) whence they pass through the second filter D to the second detector. The remainder of the circuit then follows normal practice with straight receivers.

Many variations possible

It will be appreciated that there are many variations possible in the grouping, design and use of coupling systems with tuned or untuned circuits and that de-coupling and other precautions usual with straight sets have to be incorporated to suit specific requirements.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION IX—AERIALS AND AERIAL DESIGN (1)

THE shape and size of practically every aerial used for broadcast reception is determined by the surroundings in which it is erected. Very few experimenters have the facilities for erecting special types of aerials and in any case, as far as the amateur experimenter is concerned, very little can be gained by employing specialised types of aerials for ordinary broadcast reception ; moreover, the conditions of the Post Office licence limit the total length of wire employed to 100 feet.

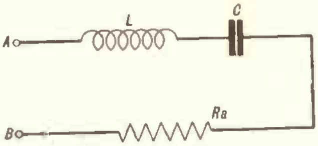


Fig. 1.—THE EQUIVALENT CIRCUIT OF A SIMPLE OPEN AERIAL.

Open and Closed Aerials

The aerials of which we are speaking now are known as OPEN AERIALS—*i.e.*, aerials whose circuit is open, there being only one connection, viz., the aerial lead. The second connection necessary to complete the aerial circuit is the earth connection, and the aerial is open in as far as there is no metallic link between the aerial itself and the second aerial connection to the receiver (the earth lead). A CLOSED AERIAL is one in which the two connections to the receiver form a completely closed circuit of *small* dimensions. A frame aerial is one example of a closed aerial.

OPEN AERIALS

Let us consider open aerials in some detail. We have seen in Section V that every length of wire possesses inductance, the actual value of inductance depending on the particular length and shape of the wire. We also know that any electrical conductor can be given a charge of electricity, and its capacity is measured by the quantity of electricity used in charging it and the potential to which it is raised when charged.

Properties possessed by an Aerial

The capacity is increased by the presence of another conducting body, or by proximity to the earth. An aerial is an electrical conductor and hence possesses a certain capacity which is dependent partly on its dimensions and partly on proximity to earth.

Various experimenters have developed formulæ for calculating both the inductance and the capacity of various types of aerials, but we shall not be concerned here with such calculations. The fact that an aerial possesses both inductance and capacity is highly important. In addition, an aerial possesses a resistance corresponding to the high-frequency resistance of a coil.

Equivalent Circuit of an Open Aerial

In Section VII, dealing with tuned circuits, we saw that a combination of inductance, capacity, and resistance formed a tuned circuit. An aerial forms a tuned circuit, and every aerial is equivalent to a series circuit comprising inductance, capacity and resistance. In discussing aerials it is often convenient to represent an aerial by its equivalent circuit, and Fig. 1 shows the equivalent circuit of a simple open aerial. By suitable choice of the values of L, C and R_a, the circuit between the terminals A and B will behave in a manner identical with that of an aerial. When the circuit of Fig. 1 is adjusted to have the values found in an aerial it is often referred to as a "dummy aerial," or as a "non-radiating aerial."

When an aerial is employed for reception it is connected to the receiver so that the aerial and earth terminals of the receiver are joined to the terminals A and B of the equivalent circuit of Fig. 1. When a signal, of any wavelength or frequency, is radiated by a station the waves reach the receiving aerial and create an electrical signal in it. The intensity of the signal depends on the size, shape, and efficiency of the aerial.

Equation for calculating Impedance

The circuit of Fig. 1 has a definite impedance which can be calculated from equation (14) of Section VI, when the values of L, C and R_a are known. The impedance is :—

$$Z = \sqrt{R_a^2 + \left(Lw - \frac{1}{Cw}\right)^2} \quad . \quad (1)$$

If the voltage induced in the aerial by the wave be E, then the current (I) through the circuit is given by :

$$E = IZ \quad . \quad . \quad . \quad . \quad (2)$$

A Practical Example

As an example, take the case of an aerial whose total inductance is 16 mH., capacity 250 m.mfd., and resistance 30 ohms.

Remembering that L and C must be expressed in henries and farads, respectively, we see that the aerial circuit impedance, at a frequency of 1,000 kc/s. (= 10^6 cycles per second), is :—

$$Z = \sqrt{30^2 + \left(\frac{16}{10^6} \times 2 \times 3{\cdot}14 \times 10^6 - \frac{10^{12}}{250 \times 2 \times 3{\cdot}14 \times 10^6}\right)^2}$$

$$i.e., Z = \sqrt{30^2 + \left(16 \times 2 \times 3{\cdot}14 - \frac{4 \times 10^3}{2 \times 3{\cdot}14}\right)^2}$$

$$i.e., Z = \sqrt{30^2 + (100 - 673)^2}$$

$$\text{or} \quad Z = \sqrt{30^2 + 573^2}$$

Now 30 is less than $\frac{1}{5}$th of 573, hence can be neglected in the square root expression. Thus :—

$$Z = 573 \text{ ohms (approx.)}$$

Receiver can be represented as a Resistance

In most cases the receiver can be represented as a resistance across the terminals A and B. If the receiver resistance be r, then the total resistance of the circuit is $(R_a + r)$, which can be represented by R for simplicity. Writing R for R_a in (1) we have :—

$$E = I\sqrt{R^2 + \left(Lw - \frac{1}{Cw}\right)^2} \quad . \quad (3)$$

As an example, suppose that the receiver resistance be 70 ohms, then :—

$$R_a + r = 30 + 70 \text{ ohms}$$

$$i.e., \quad R = 100 \text{ ohms}$$

If a voltage of 100 millivolts be induced into the aerial (note : 10^3 millivolts = 1 volt), then :—

$$100 \text{ millivolts} = 100 \div 10^3 \text{ volts.}$$

$$i.e., \quad 100 \text{ millivolts} = \frac{1}{10} \text{ volt.}$$

Putting these values in (2) we have :—

$$\frac{1}{10} = I\sqrt{100^2 + 573^2}$$

In this case 100 is just less than $\frac{1}{5}$th of 573 and can just be neglected, giving :—

$$\frac{1}{10} = I \times 573,$$

$$i.e., \quad \frac{1}{10} \div 573 = I$$

The current is in amps., and if we express it in micro-amps. (note : 10^6 micro-amps. = 1 amp.), we have :

$$I \text{ (micro-amps.)} = \frac{1}{10} \times \frac{1}{573} \times 10^6$$

$$i.e., \quad I = \frac{10^5}{573} \text{ micro-amps.}$$

$$\text{or} \quad I = 174{\cdot}5 \text{ micro-amps.}$$

This is the current which will be available for operating the input of the receiver.

When the Impedance is small

If the receiver resistance be approximately the same at all wavelengths, then the impedance has a large value except at resonance, when a minimum value is reached (see Fig. 5 of Section VII). When the impedance is small the effect of the aerial on the receiver is as if the aerial and earth terminals were short-circuited. Thus, at resonance, the aerial acts as a short-circuit to the input terminals of the receiver. We shall refer to this effect later when we consider aerials for short-wave reception.

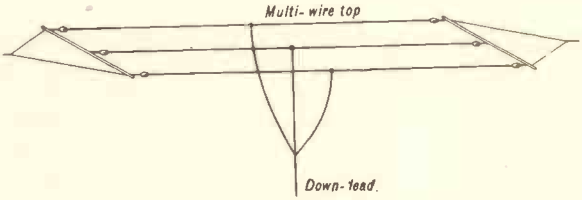


Fig. 2.—A Multi-wire Top Aerial.
Very little is gained by employing an aerial of this type.

Most frequently used types of Aerials

Of the various types of open aerials which can be erected, only three are most frequently used. These are (1) the inverted L type, (2) the T type, and (3) the vertical wire aerial. They are all named by virtue of their shape, and the terms need no further explanation.

Basic Principles which Govern these Types of Aerials

There are certain basic principles which govern the performance of these types of aerials, and which must be observed if a maximum energy is to be induced in the aerial from any one wave—*i.e.*, if the optimum signal is to be available for operating the receiver. These may be stated briefly thus :—

(1) For a given length of wire the aerial is most effective when the wire is entirely vertical, and in the case of inverted L and T types, the best aerial is obtained when the vertical portion is a maximum.

(2) In the case of inverted L and T types, where the height is limited, increasing the horizontal portion up to a length two or three times the vertical portion gives a more effective aerial.

(3) Very little is gained by employing multi-wire top aerials (see Fig. 2).

(4) The natural wavelength of an inverted L, single wire, aerial is almost exactly four times the total length of wire in the aerial. This is less accurate in the case of the T type aerial.

Effective Height.

Let us consider these points in more detail. We see that the effectiveness of an aerial depends on its total height in the case of a single vertical wire, and on its vertical height and on the length of its horizontal portion in the other cases. Every aerial, of whatever shape, has what is known as an EFFECTIVE HEIGHT, and when the value of its effective height is known the intensity of the signal induced by any particular wave is also known. The greater the effective height the greater the signal intensity in the aerial and *vice versa*. With a single vertical wire the effective height (H) is a simple fraction of the actual height (h). We have :—

Effective height (H) = ·512 × actual height (h),

i.e., $H = \cdot 5h$ (approx.) . (4)

Thus, in the case of a 25 feet single vertical wire aerial, the effective height is :—

$H = \cdot 5 \times 25$ feet,

i.e., $H = 12\cdot 5$ feet.

It is often useful to express H in metres, in which case we have :—

1 foot = ·30 metres (approx.)

hence 12·5 feet = 12·5 × ·30 metres,

i.e., H = 3·75 metres.

In the other two cases—*i.e.*, the inverted L and T type aerials—the effective height is less than the value ·512 h, where h is now the total length of wire in the aerial.

Inverted L Aerial

In Fig. 3 is shown the diagram of an inverted L aerial, the length of the vertical and horizontal portions being h_1 and h_2 feet respectively. To illustrate the effect of increasing the length of the horizontal portion of an aerial the curve of Fig. 4 has been drawn. In the example h_1 was taken as 30 feet, and values of effective height (H) were calculated for various values of h_2 from 0 to 70 feet. It will be seen that a considerable increase in horizontal length is needed beyond about 50 or 60 feet if any further worth while increase in effective height is desired. On the other hand, adding only a 10 feet top to the 30 feet vertical wire gives a 25 per cent. increase in H. By employing a multi-wire top, containing two, three, or four wires, an increase in effective height is obtained, but the increase is of the order of not more than 10 per cent., an amount which, in terms of the increase in output from the loud speaker, is barely appreciated by the ear.

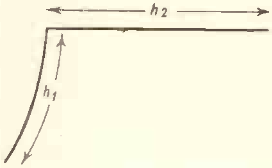


Fig. 3.—AN INVERTED L AERIAL.

H_1 and H_2 represent the vertical and horizontal portions of the aerial respectively.

Effect of Wire on Efficiency of Aerial

Increased aerial efficiency is also obtained by employing good quality copper wire. The wire should be stranded and each strand enamelled separately. Convenient sizes to use are 3/18 S.W.G. and 7/22 S.W.G. sizes, *i.e.*, three strands of No. 18 S.W.G., and 7 strands of No. 22 S.W.G. Phosphor bronze wire is sometimes used as it is more able to withstand atmospheric erosion. It is certainly preferable to bare copper wire on this account, but is inferior to enamelled copper wire, whether stranded or not. Cotton-covered stranded copper wire will also withstand atmospheric corrosion. The feature of the separate enamelled strands is that the high-frequency resistance of the wire is less than that of solid wire and of stranded wire without enamel.

Wires in which any iron is present are, as a general rule, less efficient for use as an aerial than copper wires of similar dimensions. They can only be recommended on the grounds of very great tensile strength. Such wires were used very much by H.M. Forces during the Great War because of their strength, the inefficiency being of secondary importance since sufficient power was usually

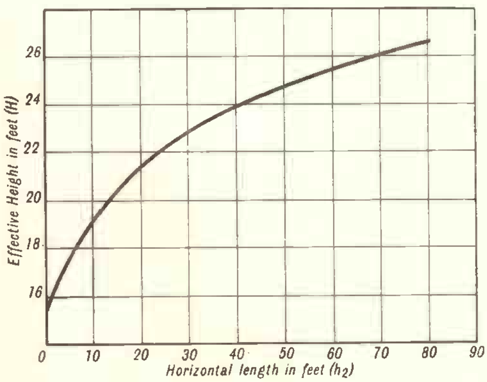


Fig. 4.—CURVE SHOWING THE EFFECT OF INCREASING THE LENGTH OF THE HORIZONTAL PORTION OF AN AERIAL.

available to compensate for the losses.

Angular Frequency at Resonance

When a signal is induced in the aerial by an incident wave the impedance at any frequency is given by (1). At resonance the reactance is zero. Let us call the angular frequency at resonance w_0. Then we have :

$$Lw_0 = \frac{1}{Cw_0}.$$

In the example already considered, we have L = 16 mH., and C = 250 m.mfd. Hence we can find w_0, angular frequency of resonance of the aerial. Another way of writing the resonance condition is :—

$$LCw^2 = 1.$$

In this equation L and C are in farads and henries, respectively, hence converting the values for L and C for our particular aerial into these units, and writing these new values in this equation, we have :—

$$\frac{16}{10^6} \times \frac{250}{10^{12}} \times w_0^{\,2} = 1,$$

i.e., $$\frac{1}{250 \times 10^{12}} \times w_0^{\,2} = 1,$$

or $$w_0^{\,2} = 250 \times 10^{12},$$

i.e., $$w_0 = \sqrt{250 \times 10^{12}},$$

i.e. $$w = 10^6 \times \sqrt{250},$$

or $$w_0 = 10^6 \times 15{\cdot}82.$$

Finding the Actual Frequency

This is the angular frequency, and we can find the actual frequency by putting $w_0 = 2\pi f_0$, where f_0 is the actual frequency. (It will be remembered that we have made this substitution several times before.) Then :—

$$2\pi f_0 = 10^6 \times 15{\cdot}82$$

i.e. $f_0 = \frac{15 \cdot 82 \times 10^6}{2 \times 3 \cdot 14}$,

i.e. $f_0 = 2 \cdot 525 \times 10^6$,

f_0 is in cycles per second. Thus the natural frequency of our particular aerial is $2 \cdot 525 \times 10^6$ cycles per second, or 2,525 kc/s. This corresponds to a wavelength of 119 metres, which is thus the natural wavelength of the aerial.

When Angular Frequency is different from Resonant Frequency

When the angular frequency of the incident wave is different from the resonant frequency, Lw is not equal to $\frac{1}{Cw}$. $\left(\text{Note: this is written } Lw \neq \frac{1}{Cw}.\right)$ If this incident signal frequency be w and w is less than w_0 (written $w < w_0$) we have :—

$$Lw < Lw_0,$$

also $\frac{1}{Cw_0} < \frac{1}{Cw}$,

but $Lw_0 = \frac{1}{Cw_0}$,

hence $Lw < \frac{1}{Cw}$.

In other words the nett reactance $\left(Lw - \frac{1}{Cw}\right)$ is negative, since the positive reactance (Lw) is smaller than the negative reactance $\left(\frac{1}{Cw}\right)$.

Negative Reactance

In the case of our particular aerial, at a frequency of 1,000 kc/s. ($= 10^6$ cycles per second), we have :—

$$w = 2\pi 10^6$$

i.e. $w = 2 \times 3 \cdot 14 \times 10^6$,

also $w_0 = 15 \cdot 82 \times 10^6$.

Now $2 \times 3 \cdot 14 \times 10^6 < 15 \cdot 82 \times 10^6$,

i.e. $w < w_0$.

Also $Lw = \frac{16}{10^6} \times 2 \times 3 \cdot 14 \times 10^6$,

i.e. $Lw = 16 \times 2 \times 3 \cdot 14 = 100$

and $\frac{1}{Cw} = \frac{10^{12}}{250 \times 2 \times 3 \cdot 14 \times 10^6}$,

i.e. $\frac{1}{Cw} = \frac{4 \times 10^3}{2 \times 3 \cdot 14} = 673$.

Now $100 < 673$,

i.e. $Lw < \frac{1}{Cw}$,

and the nett reactance is $\left(Lw - \frac{1}{Cw}\right)$ ohms,

i.e. $100 - 673 = -573$ ohms.

That is to say, the nett reactance is negative, or condensive.

The positive reactance (inductive reactance) is less than the negative reactance (capacitive reactance), and the circuit behaves as though it were composed of a nett negative reactance and a pure resistance.

Now, when $w < w_0$ the aerial is being used for the reception of signals of frequency *less* than the resonant, or natural, frequency, *i.e.*, the wavelength of the incoming signal is *greater* than the natural wavelength of the aerial. In this case we may replace the general equivalent aerial circuit of Fig. 1 by that of Fig. 5 in which the capacity of C_1 is different from that of C. The *reactance* of C_1 is actually equal to the *total reactance* of L and C of Fig. 1,

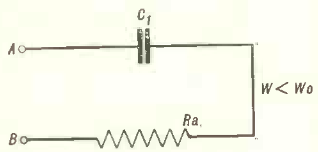


Fig. 5.—Alternative Equivalent Circuit for an Aerial.

i.e. $-\frac{1}{C_1 w} = Lw - \frac{1}{Cw}$,

i.e. $\frac{1}{C_1 w} = \frac{1 - LCw^2}{Cw}$,

i.e. $$C_1 = \frac{C}{1 - LCw^2} \quad . \quad . \quad (4)$$

In the case just cited, we have :—

$$Lw - \frac{1}{Cw} = -573 \text{ ohms},$$

and $w = 2 \times 3 \cdot 14 \times 10^6$.

If we represent the nett reactance of L and C by the reactance of a condenser of capacity C_1 m.mfd., we have :—

$$-\frac{10^{12}}{C_1 \times 2 \times 3 \cdot 14 \times 10^6} = -573$$

i.e. $\frac{10^6}{C_1 \times 6 \cdot 28} = 573$

i.e., $\frac{C_1 \times 6 \cdot 28}{10^6} = \frac{1}{573}$

which gives

$$C_1 = \frac{10^6}{573 \times 6{\cdot}28} \text{ m.mfd.}$$

or

$$C_1 = 278 \text{ m.mfd. (approx.).}$$

That is to say, the aerial acts as a condenser of capacity 278 m.mfd. at a wave-length of 300 metres.

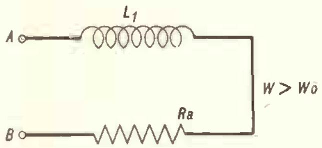


Fig. 6.—Showing how the Aerial Behaves as though it were an Inductance L_1 together with Resistance R_a.

From (5) we see that the actual value of C_1 depends on the frequency of the incoming signal. L and C are, of course, fixed since they depend entirely on the shape and size of the aerial. It can be shown that when the aerial is used for the reception of waves of length three and four times the natural wavelength, C_1 is only slightly larger than C (actually about $1{\cdot}1 \times C$).

When Optimum Reception is obtained

A complex analysis, which will not be introduced here, will also show that optimum reception (*i.e.*, optimum signal input to the receiver) is obtained by employing a variable condenser in series with the aerial, and adjusting it for each wavelength so that the aerial and receiver input circuits are correctly balanced. It follows from this that in order to compare the relative strengths of two signals of different wavelength it is necessary to employ a variable aerial coupling, such as the series aerial condenser just referred to, and to adjust for maximum signal at each wavelength to which the receiver is tuned. This process does not take account of selectivity, and where increased selectivity is desired it is necessary to upset the balance between the two circuits by decreasing the aerial coupling.

Short Wave Reception

When $w > w_0$ we have the case of short wave reception, for the wavelength of the incoming signal is now shorter than the natural wavelength. The natural wave-length (l_0) of a 100 feet aerial (inverted L type) is 4×100 feet, and expressing the aerial length in metres, $l_0 = 4 \times 30{\cdot}5$ metres, or 122 metres (approx.). Waves shorter than 100 metres are usually referred to as short waves. In this case:

$$Lw > Lw_0$$

and $$\frac{1}{Cw_0} > \frac{1}{Cw},$$

but $$Lw_0 = \frac{1}{Cw_0},$$

hence $$Lw > \frac{1}{Cw}.$$

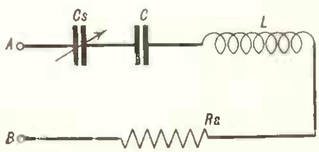


Fig. 7.—Another Equivalent Circuit of an Aerial.

In series with the aerial capacity is shown a variable capacity C_s.

When the aerial which we have already considered is used for reception of signals of wavelength 50 metres (frequency $= 6 \times 10^6$ cycles per second), we have :—

$$w = 2 \times 3{\cdot}14 \times 6 \times 10^6,$$

$$\text{and } w_0 = 15{\cdot}82 \times 10^6.$$

Now $2 \times 3{\cdot}14 \times 6 \times 10^6 > 15{\cdot}82 \times 10^6$,

hence $$w > w_0.$$

Also $Lw = \frac{16}{10^6} \times 2 \times 3{\cdot}14 \times 6 \times 10^6$ ohms,

i.e. $Lw = 600$ ohms.

and $$\frac{1}{Cw} = \frac{10^{12}}{250 \times 2 \times 3{\cdot}14 \times 6 \times 10^6} \text{ ohms},$$

i.e. $\frac{1}{Cw} = 95{\cdot}5$ ohms.

Now, $600 > 95{\cdot}5$,

i.e. $$Lw > \frac{1}{Cw}.$$

The nett reactance is inductive, and the aerial behaves as though it were an inductance L_1, together with resistance R_a, as in Fig. 6, where the *reactance* of L_1 is equal to the *total reactance* of L and C of Fig. 1,

i.e. $$L_1 w = Lw - \frac{1}{Cw},$$

or $$L_1 = \frac{LCw^2 - 1}{Cw^2} \quad . \quad . \quad . \quad . \quad (5)$$

It can be shown that L_1 is less than L, and that when the wavelength is $\frac{1}{3}$ or $\frac{1}{4}$ of l_0, L_1 is slightly greater than $0{\cdot}9 \times L$.

Damping Effect

We have already seen that at the resonant wavelength the aerial acts almost as a short-circuit across the receiver input terminals. The effect of this on the receiver is to "deaden" or "damp out" the response to signals of that particular wavelength. Great difficulty is then experienced in obtaining satisfactory reception from a station with a wavelength of l_0.

How Damping Effect of the Aerial on the Receiver is Reduced

In order to reduce the damping effect of the aerial on the receiver the coupling between the aerial and the receiver must be reduced very considerably and this results in a poor transfer of signal energy from aerial to receiver.

When this Effect would be Unimportant

This would be quite unimportant if the effect occurred only at the resonant wavelength, for we have just seen that $l_0 = 122$ metres (approx.) for a 100-feet aerial, and this wave-length is certainly of no interest to the ordinary listener.

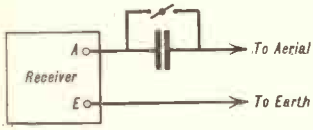


Fig. 8.—Showing the Use of a Small pre-set Condenser in Series with the Aerial Lead of the Receiver.

Aerial Harmonics

Unfortunately the damping effect of aerial resonance also occurs at fractions of the natural wavelength, viz., at $l_0, \frac{l_0}{2}, \frac{l_0}{3}, \frac{l_0}{4}$, and so on. The points in the wavelength scale where the damping effect is experienced are known as the AERIAL HARMONICS, l_0 being called the first harmonic, $\frac{l_0}{2}$ the second harmonic, and so on. $\frac{l_0}{10}$ is thus the tenth harmonic.

Variable Capacity causes Resonant Wavelength to vary

Consider the circuit of Fig. 7 representing the equivalent circuit of an aerial. In series with the aerial capacity is shown a variable capacity C_s. The total capacity in circuit depends on the adjustment of C_s. As C_s is varied the resonant wavelength of the aerial is varied. This may be shown as follows: C and C_s in series represent a single capacity C_t, where C_t can be calculated from :—

$$\frac{1}{C_t} = \frac{1}{C} + \frac{1}{C_s},$$

i.e.

$$\frac{1}{C_t} = \frac{C + C_s}{CC_s},$$

or

$$C_t = \frac{CC_s}{C + C_s}.$$

The resonant frequency of the circuit is given by the resonant condition, viz. :—

$$LC_t w_s^2 = 1,$$

$$i.e., \; L \times \frac{CC_s}{C + C_s} \times w_s^2 = 1,$$

or

$$w_s = \sqrt{\frac{C + C_s}{LCC_s}}. \qquad (6)$$

In the case of our particular aerial we found that the resonant angular frequency was $w_0 = 15{\cdot}82 \times 10^6$. If we connect a 200 m.mfd. condenser in series with the aerial lead, the new resonant angular frequency will be w_s, and can be calculated from (6). In (6) the inductance and capacity values are in henries and farads, respectively. Thus, expressing the particular values of inductance and capacity for our aerial in these units we have :—

$$w_s = \sqrt{\frac{\frac{250}{10^{12}} + \frac{200}{10^{12}}}{\frac{16}{10^6} \times \frac{250}{10^{12}} \times \frac{200}{10^{12}}}}$$

$$i.e., \; w_s = \sqrt{\frac{\frac{450}{10^{12}}}{\frac{16 \times 250 \times 200}{10^6 \times 10^{12} \times 10^{12}}}}$$

$$i.e., \; w_s = \sqrt{\frac{450 \times 10^6 \times 10^{12}}{16 \times 250 \times 200}}$$

$$i.e., \; w_s = \sqrt{\frac{9 \times 10^6 \times 10^{12}}{16 \times 10^3}}$$

$$i.e., \; w_s = \sqrt{\frac{9 \times 10^{12} \times 10^3}{16}}$$

$$i.e., \; w_s = \frac{3}{4} \times 10^6 \sqrt{1000}.$$

or $w_s = 23{\cdot}8 \times 10^6$.

That is to say, the natural frequency of the aerial system has now been increased. This value of w_s corresponds to an actual frequency $f_s = 3 \cdot 8 \times 10^6$ cycles per second, or 3,800 kc/s. The natural wavelength is thus moved from 119 metres to 79 metres.

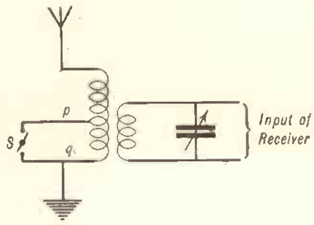


Fig. 9.—DIAGRAM SHOWING THE USE OF AN INDUCTANCE OF A FEW TURNS OF WIRE, IN PLACE OF THE CAPACITY.

Small Capacity—Small Natural Wavelength

Equation (6) shows that w_s—the resonant angular frequency *with* the series aerial condenser—depends, amongst other factors, on the capacity of C_s. It can be shown that when C_s is very much smaller than the actual aerial capacity C, the value of w_s is very large. That is to say, when a very small capacity is joined in series with the aerial lead, the natural frequency of the aerial system is very large, and thus the natural wavelength is small.

Large Capacity has little Effect

It can also be shown that when the capacity C_s is large compared with C, then the natural frequency of the system is almost the same as if C_s were out of circuit. That is to say, when a large value of series capacity is employed the natural wavelength of the aerial system is almost the same as the natural wavelength when no series condenser is employed.

Thus it will be seen that when a variable condenser is used in series with the aerial lead the capacity of C_s can be varied from a value small in comparison with C (the minimum capacity of the condenser), to a value large in comparison with C (the maximum capacity of the condenser). This will cause the natural wavelength of the aerial to be varied. The range of variation of natural wavelength of the aerial system is from a value considerably less than l_0 (C_s very small) up to a value almost the same as l_0 (C_s very large compared with C). This is illustrated by the foregoing example where the natural wavelength can be varied from 79 metres to 119 metres by employing a variable condenser with a minimum capacity of 200 m.mfd.

Variation in Aerial Harmonics

The result of varying the natural wavelength of the aerial is that the aerial harmonics are varied from $l_0, \frac{l_0}{2}, \frac{l_0}{3}, \frac{l_0}{4}$, etc., to $l_s, \frac{l_s}{2}, \frac{l_s}{3}, \frac{l_s}{4}$, etc. In illustration of this consider the case of an aerial with a natural wavelength of 120 metres. The harmonics are 120, 60, 40, 30, 24, 20 metres, etc. Now connect a variable condenser in series with the aerial lead. When the capacity is reduced the natural wavelength is shifted from 120 metres to, say, 100 metres. The harmonics are now 100, 50, 33⅓, 25, 20 metres, etc. The "dead spots" in reception have now been shifted from the first series of harmonics to the second series. A further adjustment of the series condenser will give a fresh series of harmonics—*i.e.*, a fresh series of "dead spots."

Removal of "Dead Spots."

The practical conclusion from this is that when a normal broadcast aerial is employed for short-wave reception the "dead spots" in tuning can be removed by fitting a variable condenser in series with the aerial lead. As the "dead spots" are reached in the tuning scale the series condenser is adjusted. In the case just cited, as the 40-metres wavelength region is reached the series condenser is adjusted so that the "dead spots" occur in the regions around the second series of harmonics. When the 50-metres region is reached the harmonics are shifted back again by increasing the capacity of the series condenser.

Using a Small Pre-set Condenser

An alternative to employing a variable condenser is to use a small pre-set condenser, as shown in Fig. 8, in series with the aerial lead of the receiver, and to connect a switch S across it so that it can be short-circuited. The "dead spots" are then moved from one series to a second series, the actual positions depending on the adjustment of the condenser.

LOW-FREQUENCY AND SMOOTHING CHOKES

By FRANK PRESTON, F.R.A.

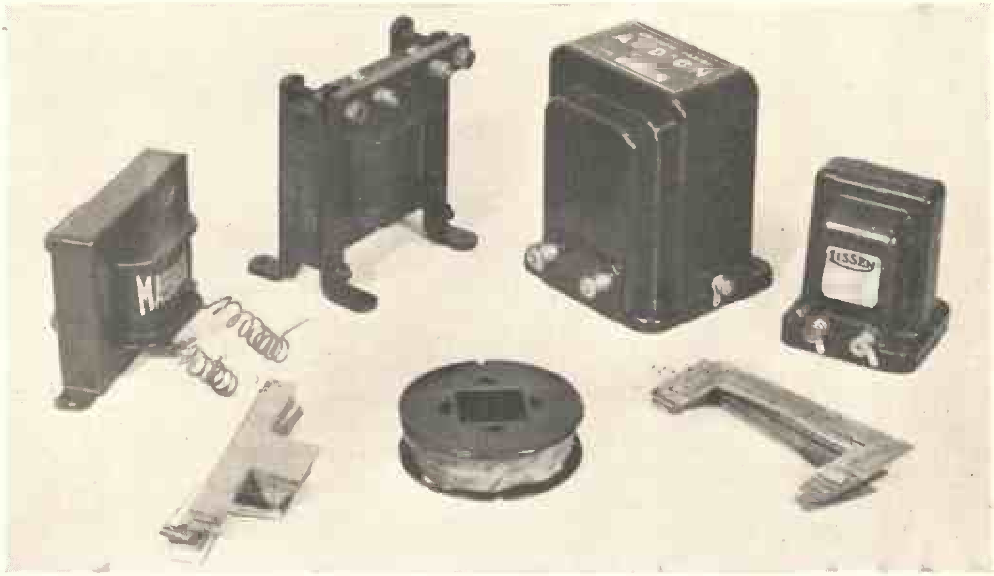


Fig. 1.—Some Examples of Low-Frequency and Smoothing Chokes.

From left to right.—" Savage " smoothing choke of the manufacturers' type (long wire connections replace terminals) ; 30-henry smoothing choke of the usual type ; Graham Farish 40-henry choke suitable for either L.F. coupling, choke capacity coupling or smoothing ; Lissen 30–60-henry choke, with nickel alloy core ; in front, principal parts of a choke, showing " T " and " U " stampings and the wound spool.

In considering high-frequency chokes we saw that their principal function was to impede the passage of high-frequency currents. Low - frequency chokes operate in a similar manner in regard to low-frequency currents below, say, 10,000 cycles. A good L.F. choke should offer a high impedance to all alternating currents having a frequency lower than 10,000 cycles, but at the same time its resistance to D.C, current should be as low as possible.

Uses of L.F. Chokes

L.F. chokes are employed principally for coupling together low-frequency valves in the manner indicated in Fig. 2, The object of the two chokes marked " 1 " and " 2 " is to feed the high-tension supply to the anodes of the first two valves, though preventing the audio (speech and music) frequencies from passing into the H.T. circuit. The audio-frequencies are in fact diverted along the paths indicated by arrows.

The purpose of the two ·005 mfd. condensers is merely to prevent the steady anode potential being applied to the grids of the low-frequency valves, whilst the ·25 megohm grid leaks serve to apply suitable values of negative grid bias.

The values of condensers and grid leaks

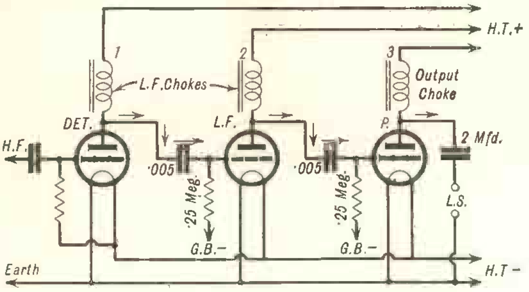


Fig. 2.—A Choke Capacity Coupled Amplifier.

are not critical but those indicated are average ones.

Choke-Capacity Coupling

Choke-capacity L.F. coupling is not used very extensively at the present time although it was more popular a few years ago. The reason for its fall in popularity is that the choke does not, in itself, give any voltage amplification as does the more popular L.F. transformer. In consequence the only amplification obtained is that of the valves themselves.

Earthing the Core

A sketch showing the connections for a choke-capacity amplifier is given in Fig. 3. The sketch shows one point we have not yet considered—a connection to earth is made from one terminal on the choke. The latter terminal is connected internally to the metal core and the earth connection often tends to improve stability.

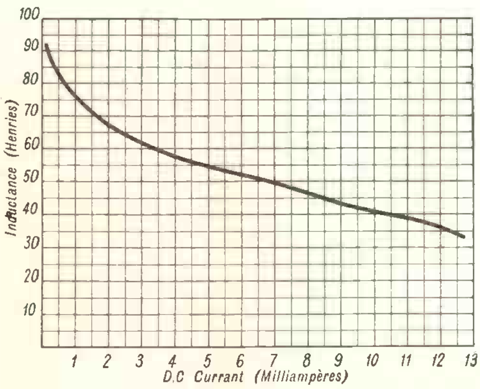


Fig. 4.—A Typical Curve Showing how the Inductance of a Choke Varies with the Current Passing through its Windings.

Some makes of choke are not provided with an earth terminal but in such cases it is generally possible to make connection to one of the core clamping bolts if necessary. One or two manufacturers connect the metal screw eyelets to the core so that the latter may be earthed from a holding-down screw.

Finding the Correct Inductance

Having decided to make a choke capacity amplifier the question arises as to what type and inductance of chokes are necessary.

Let us first consider the choke required for position " 1 " in Fig. 2. Now the full amplification of the preceding valve can

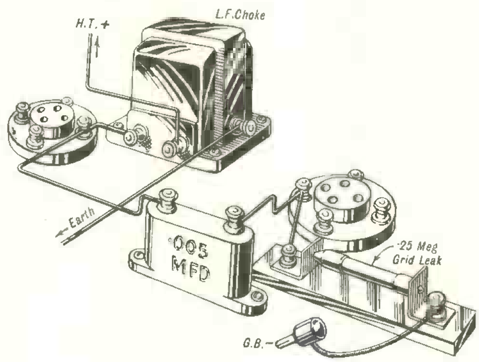


Fig. 3.—Here are shown the Connections for a Choke Capacity Amplifier.

only be obtained if the choke offers an impedance of at least twice that of the valve at all frequencies. And since the impedance of any choke is proportional to the frequency of the current applied to it, we must ensure that the choke will be of ample inductance at the lowest frequency at which full amplification is required. (If the inductance became less than the amount stated at any frequency full amplification would not be given to signals of that frequency.)

Inductance Proportional to Frequency

For most practical purposes the lowest frequency at which full response is required is about 50 cycles per second. Assuming the impedance of the detector valve in Fig. 1 to be, say, 12,000 ohms, the choke must therefore offer an impedance of 24,000 ohms (twice 12,000) at 50 cycles.

The equation connecting inductance and impedance is :—

$$\text{Inductance (in henries)} = \frac{\text{Required Impedance (in ohms)}}{2\pi f}$$

where π takes its usual value of 3·14 and f represents the frequency.

Substituting our predetermined values in this equation we find that the inductance should be $\frac{24{,}000}{2 \times 3{\cdot}14 \times 50}$, which cancels out to approximately 80 (henries).

We have now established the fact that choke "1" should have an inductance of at least 80 henries if we are to get full response down to 50 cycles.

Inductance and Current

But there is still another point to consider because the inductance of a choke varies not only with the frequency of the alternating currents but also with the amount of direct current passing through its windings. For example, a choke rated at 80 henries might actually have such an inductance when passing an infinitely small D.C. current but the inductance would probably drop to half that value if the current were increased to, say, 10 milliamperes; this point will be more easily understood by referring to the typical "Inductance — D.C. Current" curve in Fig. 4. It will be clear, therefore, that a choke must be chosen which has a suitable inductance *when passing the required amount of anode current* (that consumed by the preceding valve).

Particulars regarding the inductance under varying conditions of current are now supplied by most manufacturers of repute.

Inductance of Choke "2."

The correct inductance for choke "2" in Fig. 2 can be calculated in the manner just outlined by taking into consideration the impedance of the first L.F. valve.

Output Chokes

The output choke (marked "3") shown in Fig. 2 performs the same function as chokes "1" and "2" but is used to provide a choke-capacity loud speaker filter. For the sake of simplicity a sketch of a choke-capacity output filter is given in Fig. 5.

A filter of this kind is useful in isolating the loud speaker from the high tension supply. By so doing it saves the speaker from damage which might result from the passage of too great a current through its windings and also obviates the possibility of receiving a shock when touching the speaker terminals. This latter is of especial significance when the receiver is mains-operated. The system has other advantages and enables the full output

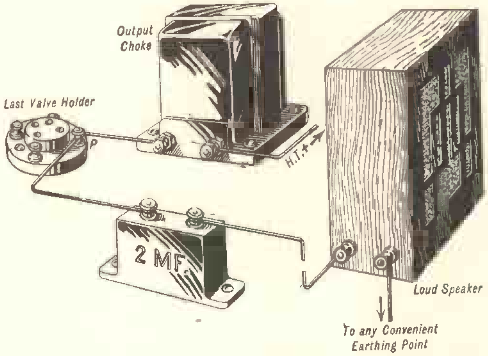


Fig. 5.—CONNECTIONS FOR A CHOKE-CAPACITY OUTPUT FILTER.

to be obtained from the last valve by choosing the choke so that it has twice the impedance of the valve—the calculation is just the same as for chokes "1" and "2."

Advantages of Choke Output Filter

An advantage which is of particular importance when the speaker is situated at a distance from the set is that a single connecting wire may be used. This is because one side of the speaker is connected to earth and the earth connection can be made at any convenient point near the speaker. When the speaker is used in the garden, for instance, it is sufficient to drive a short spike into the ground.

The advantage is not concerned merely with the economy of wire that may be effected but it has a bearing on the quality of reproduction. When a fair

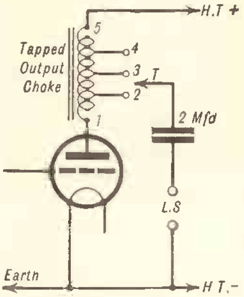


Fig. 6.—A Tapped Choke for Matching the Speaker to the Output Valve.

Different ratios are obtained by connecting "T" to tappings 1, 2, 3 and 4.

length of twin wire is used to connect the speaker there is an appreciable capacity between the wires and this causes a certain loss of strength on high notes.

Choke as 1 : 1 Transformer

The output choke just referred to acts as a 1 : 1 output transformer and in consequence the speaker will only be correctly matched to the last valve when it has an impedance equal to twice that of the valve. At least that is true in theory but in practice it is found that considerable latitude is permissible, without making any sacrifice in efficiency, when a three-electrode valve is employed in the output stage, although conditions are fairly critical in the case of a pentode.

Tapped Output Chokes

However, when using a pentode or when the speaker impedance varies considerably from the correct figure a "step-down" effect must be obtained between the valve and speaker. The step-down could be effected by means of a transformer but it can also be produced by using a tapped choke as shown in Fig. 6.

Different Ratios

The choke shown has three equidistant tappings and can be made to provide four alternative ratios. By connecting tappings "T" to terminal 1 the ratio is 1 : 1, taking it to terminal 2 increases the ratio to 3 : 1, whilst moving it to terminals 3 and 4 alters the ratio to 2 : 1 and 4 : 1 respectively. It will have been gathered that the ratio is represented by the proportion between the total number of turns on the whole winding and those between terminal 5 and the tapping output.

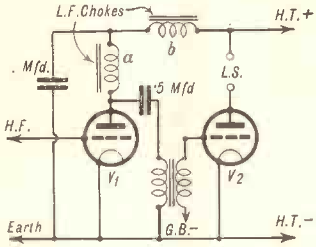


Fig. 7. — How Low-Frequency Chokes can be used to Replace Resistances.

Matching the Loud Speaker

Before leaving this subject it should be explained that the correct output ratio is found from the equation :—

$$\text{Ratio} = \sqrt{\frac{\text{Optimum load of valve.}}{\text{Impedance of speaker}}}$$

The "optimum load" is equivalent to twice the impedance for three-electrode valves, but is a different factor in the case of pentodes. Incidentally, the optimum load for both power and pentode valves is generally stated on the makers' instruction sheets. (See the article "How to Match Loud Speakers to the Output Stage.")

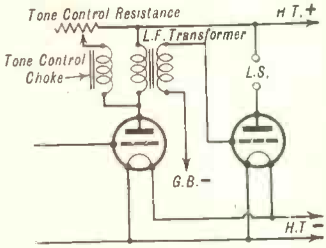


Fig. 8.—Using a Low-Frequency Choke as a Means of Effecting Tone-Control.

Chokes to Replace Resistances

It is not generally realised that low-frequency chokes can be employed to replace resistances in most A.C. circuits. An example of this is given in Fig. 7. Choke "a" takes the place of the more usual resistance employed for "resistance-feeding" the L.F. transformer. Its correct value can be found in exactly the same way as explained in reference to Fig. 2.

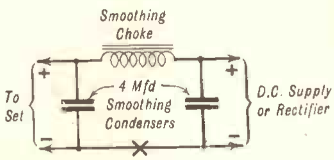


Fig. 9.—Diagram of a Typical Smoothing Circuit.

Choke for De-Coupling

Choke "b" serves as a de-coupling resistance and operates in conjunction with the 2 mfd. condenser. This component may have an inductance similar to that of "a."

Saving H.T. Voltage

Low-frequency chokes would be eminently suitable for the purposes indicated and would be very valuable where high-tension voltage was at a premium. Naturally the chokes would be much more costly than resistances and their use could only be recommended in the case of a very limited supply of high-tension voltage.

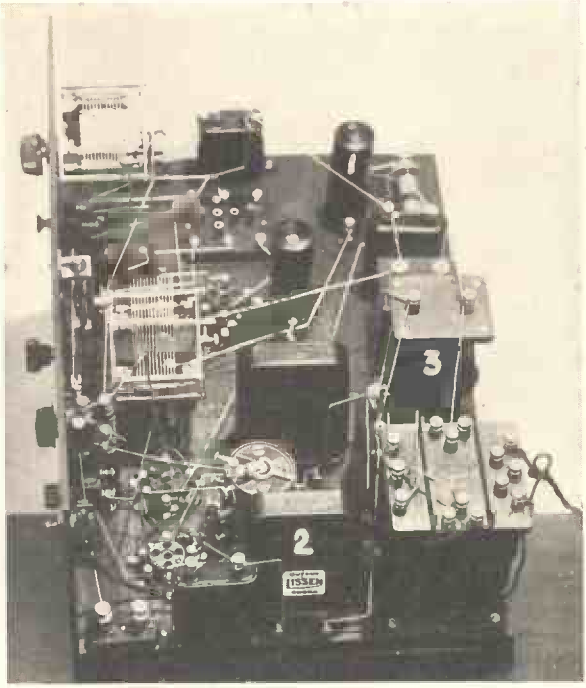


Fig. 10.—Here We See the Use of Different Types of Chokes in a Three-Valve A.C. Receiver.

1 is a low-frequency choke for choke-capacity coupling ; 2, is an output choke ; and 3 is a smoothing choke.

Tone Control Chokes

There is another use for L.F. chokes which we have not yet considered ; that is in connection with tone control circuits.

A tone control choke can be connected in numerous ways and the simplest is shown in the circuit of Fig. 8. The choke is connected, through a variable resistance, in parallel with the primary winding of the L.F. transformer. The impedance of the primary winding is reduced by putting the choke in parallel with it and in consequence the response to low notes is reduced ; low-note attenuation produces an effect equivalent to increased high-note response.

The effect of the parallel-connected choke is reduced by increasing the amount of resistance in circuit and therefore the variable resistance makes possible an even regulation in tone.

Smoothing Chokes

Chokes used for smoothing purposes in high-tension supply circuits are similar in principle and construction to low-frequency chokes, but their method of operation is quite different.

Let us consider the smoothing circuit shown diagrammatically in Fig. 9. Now the voltage supplied to it from the D.C. supply (mains or A.C. rectifier) is not of constant value but fluctuates rapidly within certain limits. If the fluctuating voltage were applied to the anodes of the receiver valves it would cause a note to be produced in the loud speaker and that would obviously spoil reception.

It will be seen that the smoothing circuit consists of two condensers in shunt with the supply, and an iron-cored choke in series with the positive lead.

The condensers do a fair amount in respect to smoothing due to their ability to "store" electricity. Briefly their function is to "absorb" electricity when the fluctuations cause the voltage to rise above the mean figure, and to discharge some of their stored-up energy when the voltage falls below the mean.

If we may draw an analogy, smoothing condensers can be likened to the road springs of a motor vehicle ; the springs "give" and "take" as the wheels traverse a bumpy road and so the tendency of the body of the vehicle is to keep in the same horizontal plane.

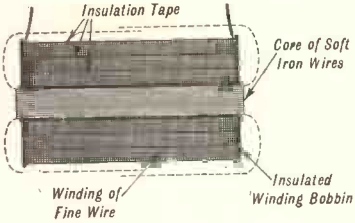


Fig. 11A.—Section through a low-priced Choke.

But the springs would not be effective if the body of the vehicle were of very light weight in comparison with the strength of the springs. It is partly due to the inertia (resistance to change of motion) of the body that the springs are effective.

Electrical Inertia

If we continue our analogy we can say that the object of the choke is to introduce a certain amount of "inertia" into the electrical system.

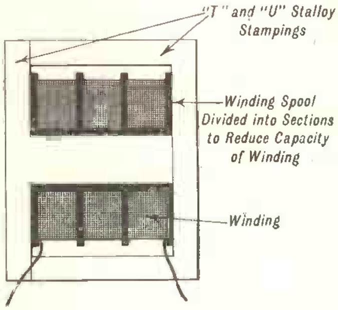


Fig. 11B.—Section through a L.F. or Smoothing Choke of Usual Pattern.

It is not difficult to see how the choke does this if we remember that the core becomes magnetised due to the current passing through the windings. Any change in current causes a change in the state of magnetism; thus a sudden increase in current would cause an increase in magnetic flux. But the latter creates a voltage (more correctly an electro-motive force) which acts in opposition to the normal current flow and this tends to counteract the sudden voltage increase. The net effect of the choke is to keep the current flowing through it at constant intensity.

Inductance of Smoothing Choke

The correct inductance for a smoothing choke cannot be calculated so easily as can that of an L.F. choke and in practice it is generally determined by experiment.

Knowing that an average value for a high-tension smoothing choke is about 25 henries we can get some idea of the correct value by studying the nature of the current supplied to it. When the latter is obtained by rectifying 50 cycle A.C. on the half-wave principle the fluctuations will occur at the rate of 50 cycles per second and the 25 henry choke will in all probability be adequate. If, however, the 50 cycle A.C. is rectified by the full-wave method the fluctuations will be twice as frequent (100 per second) and a choke of lower inductance will be able to cope with them.

When the supply is from 25 cycle mains the "fluctuation frequency," as one might call it, will be only half as great, and in consequence twice the inductance will be required to produce the same amount of smoothing. In such cases a single choke might be insufficient and a second one would be required at the point indicated by a cross in Fig. 9.

The above rules apply principally to rectified A.C. current but have equal significance in regard to D.C. although the fluctuation frequency of D.C. is generally not known and so the required inductance value must be determined purely by experiment.

It will be clear from what was said in reference to L.F. chokes that the inductance of smoothing chokes must also be determined in relation to the amount of current being dealt with.

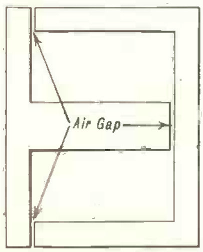


Fig. 12.—How the Stampings are Arranged in a "Gapped-core" or "Constant-Inductance" Choke.

Gapped Core Chokes

Although it has been stated that the inductance of the usual types of chokes (such as those shown in Section in Fig 11) varies with the current passing through the windings it is possible to construct a choke with a constant inductance regardless of current.

Such a choke is made as shown in Fig. 12, a small air gap being left in the circuit of the core. The gap causes a slight reduction in the effectiveness of the core and makes it necessary to use a greater number of turns for the windings. The use of gapped core chokes is more or less confined to experimental and "power" purposes although the chokes *are* used in making eliminators and mains sets of the larger kinds.

The Construction of Iron Core Chokes

Up to now we have dealt with the uses of L.F. and smoothing chokes but we have said very little in regard to their construction.

The simplest type of L.F. choke is that shown in Fig. 11 (*a*). It has a core consisting of a bundle of soft iron wires, and this is fitted into a wooden, bakelite or fibre bobbin in which the windings are placed. The latter usually consists of several thousands of turns of fine gauge wire divided into sections by layers of insulating tape. By splitting up the windings in this way capacity is reduced.

Hedgehog Chokes

The "open" core is not very efficient and, generally speaking, is only employed for small chokes which have to deal only with low current intensities.

Efficiency can be increased by employing a "closed core," that is, one in which there is a continuous magnetic circuit. This can be provided by allowing the iron wires to project at each end of the bobbin and then bending them back over the bobbin so that the two ends meet each other, as shown in broken lines in Fig. 11 (*a*). Chokes of this kind are used by a few manufacturers for smoothing purposes in low-power eliminators and are called, due to the shape, hedgehog chokes.

Closed Core Chokes

The most common type of choke for either L.F. coupling or smoothing, however, is that shown in section at Fig. 11 (*b*). Incidentally it might be pointed out that the same form of construction is employed for all those chokes shown in the photograph of Fig. 1.

The core is made up from "T" and "U" shaped laminations of Stalloy, and they are interlocked to form a closed magnetic circuit. The "Stalloy" is more efficient than ordinary iron and does not cause so much efficiency loss. A number of laminations are used in preference to a solid core because it is found that magnetism does not penetrate very deeply into a large mass.

The windings of the choke shown in Figure 11 (*b*) are divided into sections to reduce capacity and also to prevent turns at different potentials (there is always a potential drop across the windings) from coming close together and possibly causing a short circuit.

Nickel-Iron Cores

An increased efficiency, principally with L.F. chokes, is permissible by introducing a certain amount of nickel into the alloy used for the core. By employing a nickel-iron core it is often possible to reduce its size and yet maintain a high inductance. This point will be appreciated by noticing the relative sizes of the Lissen and Graham Farish chokes shown in Fig. 1. Both have similar values of inductance but the larger one (Graham Farish) has a core of Stalloy; the smaller, a nickel alloy core.

D.C. Resistance

I have left until last the question of D.C. resistance. In the case of a choke for L.F. coupling it is of little consequence, but with a choke used for a loud speaker filter or for smoothing, a high resistance can be very troublesome.

The principle difficulty caused by high resistance is that it entails a voltage drop which cannot generally be afforded. The reason will be obvious when it is realised that a choke of 2,000 ohms D.C. resistance will "drop" 100 volts when used for smoothing a 50 milliampere supply.

Of course we are bound to have some D.C. resistance and for average purposes a resistance of 700 ohms should not be considered excessive. When there is very little voltage to spare, lower resistance chokes, down to 200 ohms or so, can be obtained, but these are fairly expensive.

Allow for Voltage Drop

When designing an all-mains receiver or an eliminator one should not forget to make allowances for the voltage drop which must inevitably be created by the smoothing choke(s).

HOW TO MAKE A 2-VALVE ALL-MAINS SET

By H. E. J. BUTLER

THIS set is intended essentially for local reception at good loud-speaker strength. An outdoor aerial is desirable to obtain the maximum range, but a mains or indoor aerial will give ample volume within ten miles of the National and Regional Transmitters. The output valve is capable of delivering an undistorted output of nearly two watts, which is sufficient for domestic requirements. The power consumption of the set is less than 30 watts.

Fig. 1.—THE COMPLETED RECEIVER.
Showing panel controls of the set.

The Circuit

The wiring diagram of the complete set is shown in Fig. 6. The detector valve, a Micromesh H.L.A.1, is coupled to the aerial through a band-pass filter, consisting of a pair of Colvern K.B.L.C. coils. This particular type of band-pass filter gives constant selectivity over the whole tuning scale on both long and medium wave bands. The detector operates on the leaky-grid principle. Detector damping, which results in poor selectivity, is overcome by connecting the grid of the valve about half-way down the medium wave section of the second coil. To balance this arrangement the aerial is similarly connected to terminal No. 6 on the first of the band-pass coils.

In the anode circuit of the detector valve, a high-frequency choke prevents any high-frequency currents from being passed on to the output valve. A pair of fixed condensers, C6 and C7, serve to deflect the stray high-frequency currents to earth. The output valve is coupled to the detector stage by means of an R.I. Parafeed transformer.

A Point about the Transformer Connection

It will be noticed that the primary winding of this transformer is not connected in the anode circuit of the detector, but between the anode of the detector and earth. A 1-microfarad condenser, C9, prevents a short circuit of the high-tension supply of the detector, but allows the low-frequency impulses to pass through the transformer primary. Although this transformer is very small it gives a very high degree of quality when connected in this way, because the primary inductance is not affected by the anode current of the detector.

The Output Stage

A choke output circuit is used, to ensure freedom from low-frequency oscillation, which is always more likely to occur

Components Required

1 Mains Transformer, Type No. 232. *Rich & Bundy.*
1 Dual Gang Condenser with Disc Drive. *British Radiophone.*
2 Matched K.B.L.C. Coils on Base. *Colvern.*
1 Smoothing Choke, Type S50/50. *Tunewell.*
1 Output Choke, Type S20/25. *Tunewell.*
4 Fixed Condensers, 4 mfds., Type 84. *T.C.C.*
3 Fixed Condensers, 1 mfd., Type 84. *T.C.C.*
1 Fixed Condenser, ·05 mfd., Type 40, non-inductive. *T.C.C.*
2 Fixed Condensers, ·001 mfd., Type 34. *T.C.C.*
1 Fixed Condenser, ·0001 mfd., Type 34. *T.C.C.*
1 Pre-set Condenser, ·0003 mfd., Type J. *Formo.*
2 Valve Holders, 5-Pin, Baseboard Mounting. *Telsen.*
1 Valve Holder, 4-Pin, Baseboard Mounting. *Telsen.*
1 High-frequency Choke. *McMichael.*
1 Fixed Resistance, 250,000 ohms 1 watt Type. *Erie.*
1 Fixed Resistance, 100,000 ohms 1 watt Type. *Erie.*
2 Fixed Resistances, 25,000 ohms 1 watt Type. *Erie.*
1 Fixed Resistance, 325 ohms 1 watt Type. *Erie.*
Toggle On-off Switch, Type No. S. 102. *Bulgin.*
Mains Safety Plug, Type No. P. 18. *Bulgin.*
1 Detector Valve, Type HLA1. *Micromesh.*
1 Amplifier Valve, Type PA1. *Micromesh.*
1 Rectifier Valve, Type R1. *Micromesh.*
6-volt Miniature Screw Bulb.
$\frac{3}{8}$-inch Baseboard and Aluminium 24 S.W.G. sheet, 15 × 9 inches.
6 four B.A. Terminals and No. 4 × $\frac{3}{8}$ inches R.H. Wood Screws.
1 dozen 6 B.A. × 1 inch Cheese Head Brass Screws. *T. L. Castle.*
Ebonite Block, $\frac{1}{4}$ × 4 × $1\frac{1}{4}$ inches.
Ebonite Block, $\frac{1}{4}$ × $1\frac{1}{2}$ × $1\frac{1}{4}$ inches.
Ebonite Block, $\frac{1}{4}$ × $1\frac{1}{2}$ × $1\frac{1}{2}$ inches.
Glazite and Twin Rubber Covered Flex.

in a mains-operated receiver than in a battery set. The terminals "L.S." are connected to the primary of the speaker transformer, when a low-resistance moving coil type is used.

The High-Tension Supply

The output valve requires 40 milliamperes at 200 volts, to obtain the maximum output. The high tension D.C. is obtained by means of a valve rectifier, which is of the indirectly heated type. The smoothing equipment consists of a 50-henry choke, C.H.1, and two 4-microfarad condensers, C13 and C14. In order to adjust the high-tension voltage of the output valve to the correct value, the two chokes are chosen to drop about 50 volts. The unsmoothed high-tension voltage is about 265 volts at 45 milliamperes, so that 15 volts is left for the grid bias. Two resistances, R1 and R2, in the anode circuit of the detector valve, adjust the voltage of this valve to 100 volts. The resistance R1 also serves, in conjunction with C8, to decouple the anodes of the two valves. R2 is the feeding resistance for the L.F. transformer.

Grid Bias

A grid bias of at least 12 volts is required for the output valve. This is obtained by the resistance R5. The value of this resistance is 325 to 350 ohms; the lower value of resistance gives 13 volts bias, while the higher value gives 14 volts. R4 and C10 provide for grid decoupling of the output valve.

Baseboard Assembly

The size of the baseboard is reduced to the smallest possible dimensions by mounting the components on both sides of it. All the mains components are fixed below the baseboard, together with the low-frequency transformer and the binocular high-frequency choke. Only three wires pass through the baseboard: two for the switch and one lead forming the connection between the output and smoothing chokes.

Preparing the Baseboard

The upper side of the baseboard is faced with a sheet of 24 S.W.G. zinc or aluminium. "Plymax," or metal-faced plywood is ideal. The metal is cut $\frac{1}{16}$ inch smaller than the wood, so as to ensure that the metal does not overlap. The first stage in the construction is to screw the sheet metal to the base with $\frac{1}{4}$-inch wood screws. Six screws are sufficient at this stage, because the metal screen has to be removed after the holes have been drilled. The second operation consists in marking out and drilling all the holes in the top of the baseboard.

Layout and Wiring of the Top of the Set

Figs. 2 and 4 show the layout and wiring of the top of the set. There is no better way of marking out the baseboard than from the components themselves, because errors are least likely to arise. The variable condenser is supplied with a template for drilling its three fixing holes. Further notes on mounting a radiophone condenser are given on p. 93. These three holes are drilled right through the baseboard. Alternatively the condenser may be fixed with a special bracket, which the manufacturers supply for this purpose. The holes for the valveholder sub-baseboard connections are made ⅜ inch diameter, to give ample clearance round the 6 B.A. screws. The larger holes may be drilled with a woodworker's centre-bit, because the metal used is soft.

In order to maintain a convenient earth connection below the baseboard, the back left-hand fixing screw of the coil base carries a soldering tag below the board.

The Valve Holders

For convenience in wiring, eleven of the fourteen valve holder connections are

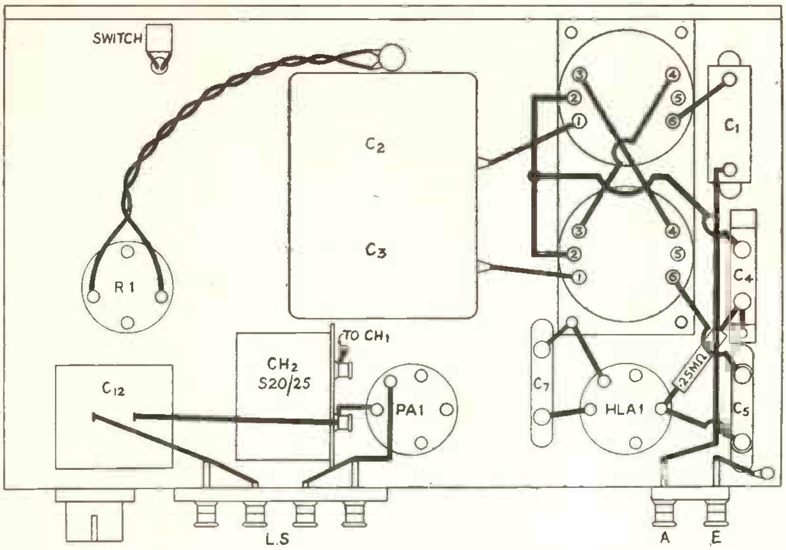


Fig. 2.—The Layout and Wiring of the Upper Side of the Baseboard.

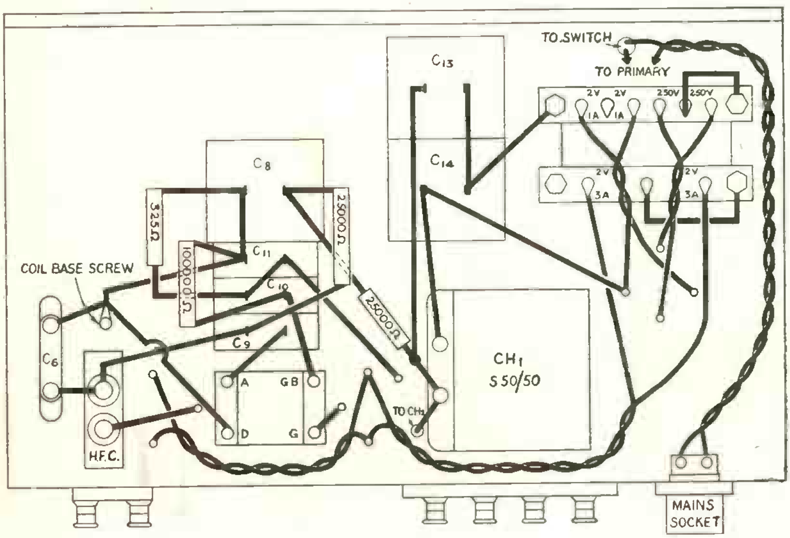


Fig. 3.—The Layout and Wiring of the Underneath.

The terminal blocks of the mains transformer are drawn, for the purpose of the diagram, on top of the component.

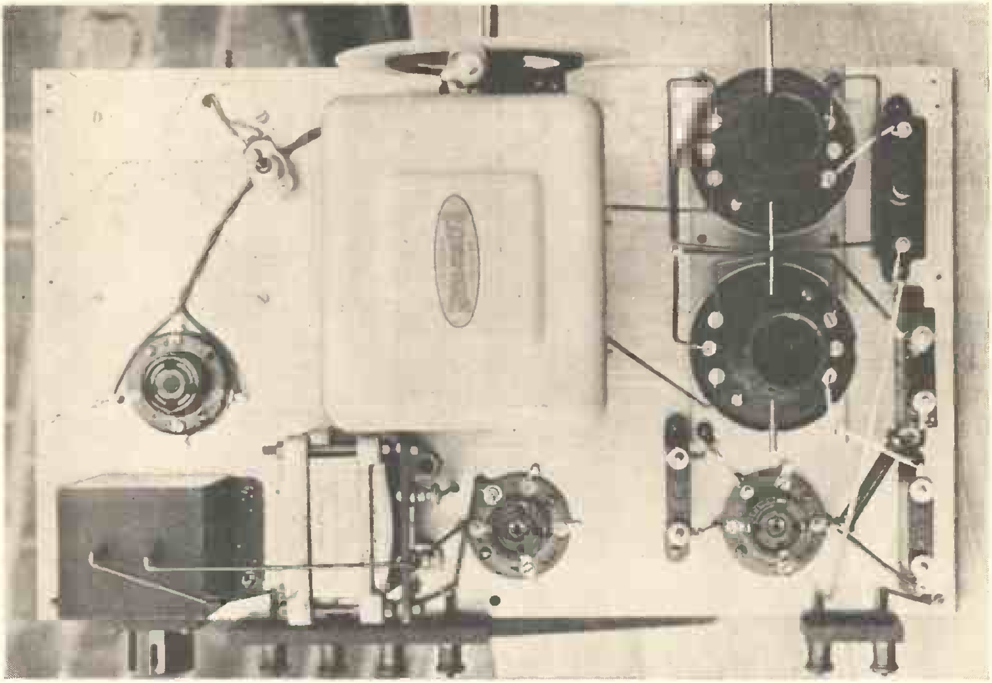


Fig. 4.—THE TOP OF THE SET WITH THE PANEL REMOVED.

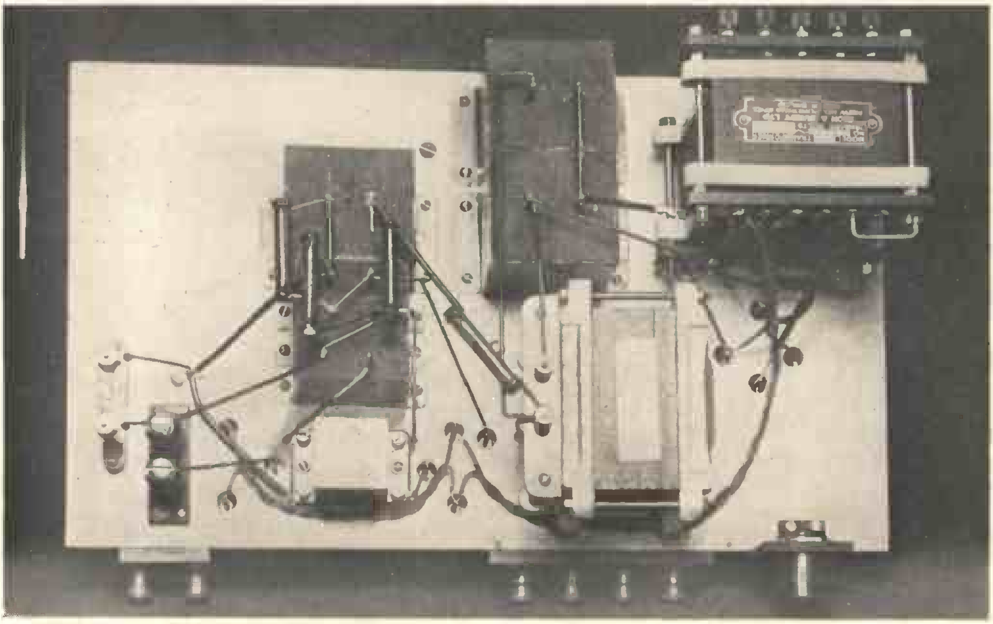


Fig. 5.—A VIEW OF THE FINISHED SET FROM THE UNDERNEATH.

made below the baseboard. This is arranged by substituting 6 B.A. screws, 1 inch long, for the terminals. The detector valve holder has the two heater and the anode connections extended below the board in this way, while the output valve holder has all but the anode connected below the baseboard. The rectifier holder has all four terminals replaced with long screws. Above the baseboard a soldering tag is placed under the

Condenser Trimmers

In order to render the tuning condenser trimmers more accessible, they are transferred to the right-hand side of the condenser assembly. A clear space is then available if the adjustments are carried out as shown in Fig. 9 before putting the set into the cabinet. The necessary holes are provided on both sides of the component, so that this is quite a simple operation.

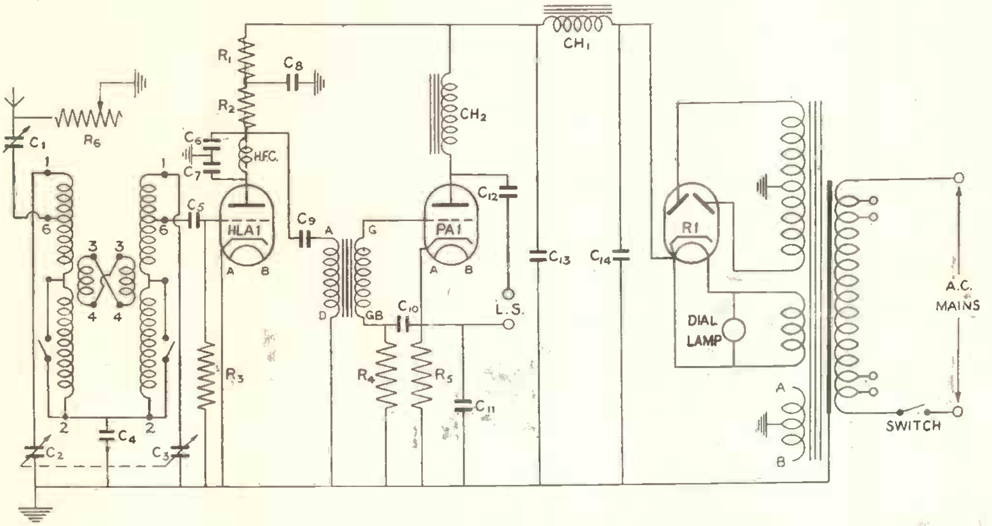


Fig. 6.—The Circuit of the Complete Receiver.

The following are the values of the components: C_1, ·0003 mfd.; C_2 and C_3, ·0005 mfd.; C_4, ·05 mfd. non-inductive; C_5, ·0001 mfd.; C_6 and C_7, ·001 mfd.; C_8, 4 mfd.; C_9 C_{10} and C_{11}, 1 mfd.; C_{12}, C_{13} and C_{14}, 4 mfd. R_1 and R_2, 25,000 ohms; R_3, 250,000 ohms; R_4, 100,000 ohms; R_5, 325 ohms; R_6, 50,000 ohms.

head of the output valve cathode screw to provide a connection for the loud speaker terminal.

Below the Baseboard

Figs. 3 and 5 show the arrangement of the components on the underneath of the set. The mains transformer is bolted right through the baseboard, not only to provide a secure fixing, but to earth the frame of this component. One of the dual-gang condenser fixing screws is located under the pair of 4-microfarad smoothing condensers, so that it is necessary to countersink this screw and also to mount the tuning condenser before fixing these in position.

Mounting the Parts

If the chassis is not to be provided with side members below the baseboard, a special order of mounting the parts must be observed. The omission of these supports considerably facilitates the wiring up. Where this method is adopted the valve holders and tuning condenser are fixed first, then all the parts are mounted and wired on the underneath. Before any of the parts are mounted, the screening plate is removed when all the burrs and drilling swath are removed. When the underneath is finished, the top can be dealt with while the set rests on the top of the transformer and a block of wood placed at the side of the decoupling condenser bank. The wiring of the coils is simplified if the two link wires between terminals 3 and 4, and the common lead joining No. 2 terminals, are wired before screwing the coil assembly to the baseboard. The panel is not fixed until the assembly and wiring has been completed as shown in Figs. 2 and 3.

Ensure Good Earth Connections

Some precautions are necessary when assembling the parts to ensure good earth connections at the various points. Firstly, examine the underneath of the tuning condenser, and if necessary remove the paint from the tapped bosses. This earth joint provides the connection of the moving blades of the condenser. It will be found that the edges of the coil base are free from paint, but it is necessary to scrape off the enamel under the two fixing screws which are used as earth connections. Another component requiring similar treatment is the mains transformer. The paint is removed from the top of all four fixing lugs, because a good earth connection is most essential for this part. This is because the earthing to the metal baseboard facing is relied upon to form the negative high-tension circuit, and to earth the primary screen.

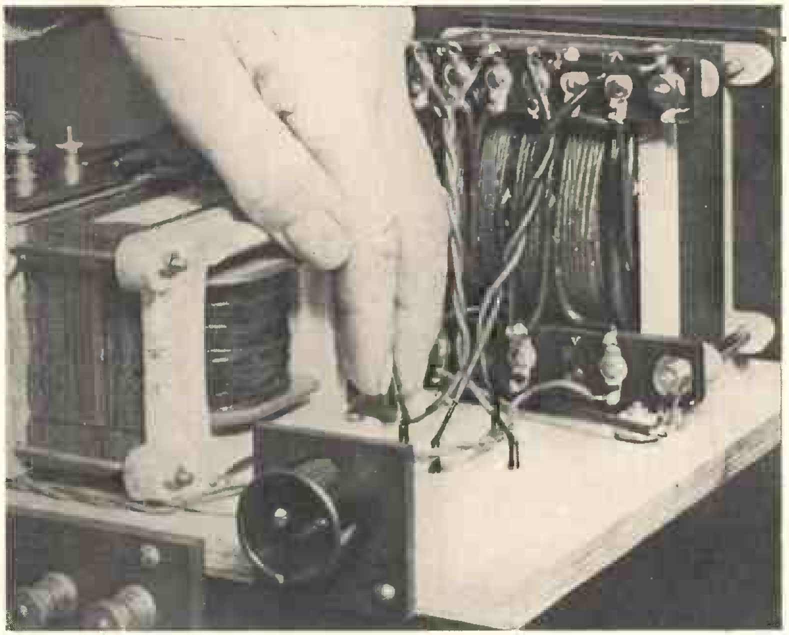


Fig. 7.—A VIEW OF THE UNDERNEATH.

Showing the transformer connections. The wire between the fingers is the H.T. positive connection.

The Wiring

Most of the connections are made with Glazite insulated wire. Flexible wire is preferable for the A.C. leads, because it conforms more readily to the path taken by these wires. A few short lengths of insulating sleeving will be found useful when wiring up the Erie resistances. On the underside of the baseboard the mains transformer and the A.C. leads are wired first. Fig. 5 shows the output connections of the mains transformer. The 500-volt leads are made with flex or Glazite having an additional protection of Sistoflex sleeving. The centre tapping of this winding is earthed on the soldering tag to which the primary screen is also connected. The centre of the 4-volt 3-ampere heater winding of the transformer is earthed to the bottom outside clamping nut as shown in Fig. 3. No connection is made to the centre tap of the 4-volt winding of the rectifier because this valve is an indirectly heated type. Unlike indirectly heated receiving valves, the rectifier of this type has no fifth pin, because the cathode is internally connected to one of the heater pins. It is essential to make the positive high-tension to this particular pin, otherwise the high-tension current will be passed through the heater in addition to the A.C. This connection is indicated in Fig. 7. Since the set wiring is done with the panel removed, the connecting of the mains plug and the transformer primary is left until last.

Wiring the Erie Resistances

The wiring of the Erie resistances calls for some care. Those below the baseboard are shown in Fig. 7. The two on the right are 25,000 ohms (red body, green tip, orange dot). The inside left-hand resistance, for grid decoupling, is 100,000 ohms. This has a brown body, black tip and yellow dot. It is necessary to solder a short extension to the 25,000 ohm resistance, which is wired between the smoothing choke and the 4-microfarad condenser. The bare ends of those resistances which are likely to make contact with other wiring or resistances, are insulated with sleeving.

Besides the two earthing points already made to the transformer frame a third, for the two microfarad smoothing condensers, is effected in the same way as shown in Figs. 3 and 5.

Wiring Above the Base

Above the baseboard the main part of the wiring consists in connecting the Colvern coils. If, as previously advised, the coils are partly wired before mounting them, there remains only five connections to make. The wires are taken through the nearest openings in the coil bases, taking care not to raise them too high or to make them bear on the sides of the slots. Coil terminals No. 5, which form the junction between the long and medium wave sections, are not wired.

Dial Light Wiring

The dial bulb holder is connected to the rectifier heater since this is the most convenient. Special attention should be given to the insulation of this wiring, because an earth here would short-circuit the high-tension secondary of the mains transformer; the insulation is retained right up to the soldering tags.

The Panel

Marking out the panel holes is best done after the components have been mounted. The two holes for the coil-switch spindle and the disc-drive spindle are marked out first, then the escutcheon is set out in accordance with the maker's pamphlet, which is supplied with the condenser. The hole for the switch is marked out symmetrically with the coil-switch knob. The switch hole is drilled $\frac{15}{32}$ inch diameter.

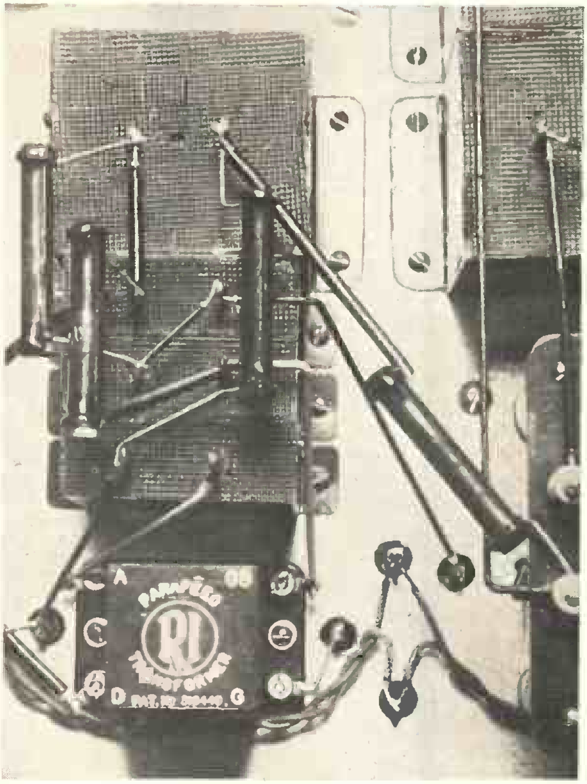


Fig. 8.—An Enlarged View of the De-coupling Condensers and the four Erie Resistances below the Base.

It is advisable to fix the panel to the base with a pair of angle brackets, so as to avoid the necessity of screwing the panel to the front of the cabinet. The panel is made from $\frac{1}{4}$-inch material; wood for preference.

The Valves

Those specified represent one of the latest developments in valve design. They have specially constructed electrodes which enable a high mutual conductance to be obtained with a generous cooling surface. Although it is not generally possible to substitute different valves in an all-mains receiver it is permissible in this instance, if one slight alteration is made. A Mazda AC2/HL may be used for the detector valve in place of the HLA.1. This does not entail any alteration to the set. The PA.1 output valve may be replaced by a Cossor 41XMP if a bias resistance of 300 ohms is substituted for the 325–350 ohms, which is necessary for the Micromesh valve. The positions of the valves in the set are shown in Fig. 2.

The Loud Speaker

A moving coil speaker is advised to obtain the best advantage from the set. When a high-resistance moving iron loud speaker is used the output terminals of the set, marked "L.S." are connected directly to the speaker. The optimum load for the output valve is 2,000 ohms, so that for direct connection the loud speaker should have an impedance near this figure. Whether the speaker is directly connected or whether it is connected through an external transformer, no D.C. passes through the speaker or the primary of the output transformer. This is a desirable feature because the anode current of the output valve is 40 milliamperes, which few moving iron speakers will stand, and most transformers suffer a loss of primary inductance.

Ganging Adjustments

When the finished set is first switched on it will be found, that in all probability the signal strength is low. This is because the two tuning circuits are each tuned to a slightly different wavelength, due to the fact that the aerial and circuit capacities are not matched. The purpose of the trimmers of the dual-gang condenser are to bring these stray capacities into line, so that provided the coils are matched, the accuracy of the ganging will hold good over the whole tuning scale.

What to Do First

The first operation in ganging the set is to screw down the aerial series pre-set condenser to its maximum capacity, that is turn the adjusting screw clockwise to the fullest extent. Next see that the trimming condensers are unscrewed. The set is now switched on, preferably with headphones connected to the output terminals. Failing headphones, the loud speaker is placed close by. Now rotate the tuning dial until a station is received at its maximum strength. With the average outdoor aerial it will be found that the screwing up of the second trimming condenser, as shown in Fig. 9, will increase the volume, thus indicating that the second coil requires more capacity to effect alignment. This trimmer is now adjusted until signal strength is a maximum. If the maximum volume is obtained with this trimmer only partly screwed down then no further adjustment should be necessary.

Adjusting the Pre-set Condenser

Suppose, however, the volume increases up to the point when the second trimmer is screwed right down. It cannot then be certain that the circuits are in line, because additional capacity may be required. If this condition is reached it shows that the aerial circuit capacity is too high. This is reduced by unscrewing the pre-set condenser half a turn. The tuning dial is now reset if necessary, to obtain the maximum strength. Adjustment of the rear trimming condenser is then retried, to find whether ganging can now be obtained with this setting of the aerial pre-set condenser. If not, the pre-set condenser is further reduced until alignment is obtained.

The chief aim when making these adjustments should be to obtain the ganging condition with the least possible trimmer capacity. If the trimming capacity is set too high it may be found that the minimum wavelength to which the set can be tuned is raised above a broadcast station which it is desired to receive.

Volume Control

Volume control is not included in the design of the set, because this is not

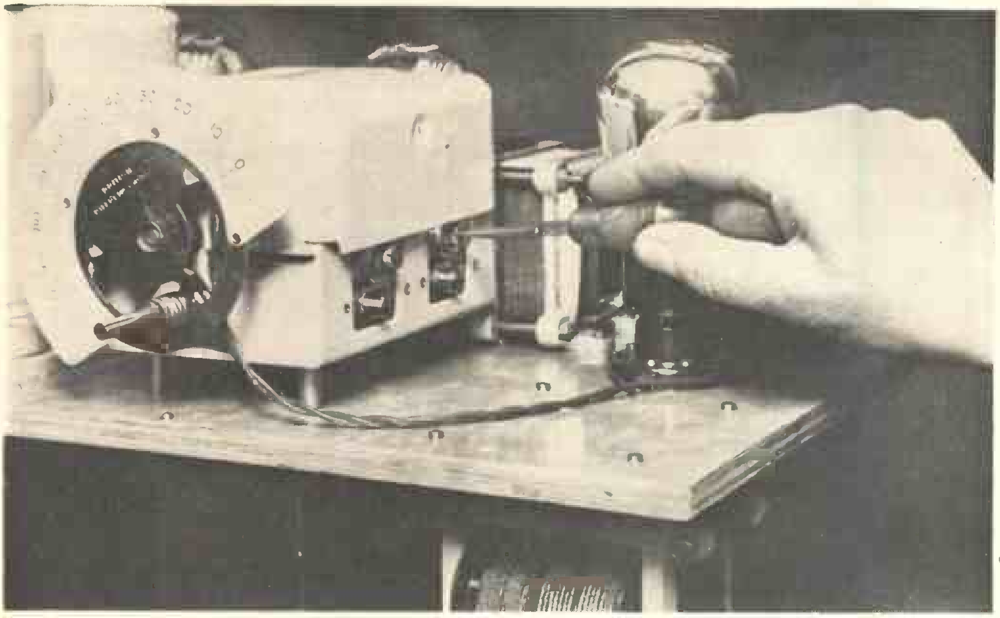


Fig. 9.—ADJUSTING THE TRIMMING CONDENSERS BEFORE PLACING THE SET IN THE CABINET.

generally required in a set of this type, where the volume of the local station can be permanently set by the adjustment of the pre-set condenser. If, however, volume control is desired, a variable resistance is connected across the aerial and earth, as indicated in Fig. 6. The value of this resistance is 50,000 ohms.

Reaction

Reaction is not advised, because however arranged in a set with no high-frequency stage, re-radiation and interference is bound to occur. A limited amount of fixed reaction may be added to give a permanent fillip to the set. This is arranged by connecting a 0·0001 mfd. pre-set condenser across the anode of the detector valve and the aerial. These two points are close together on the left-hand side at the back of the set. This condenser is set whilst the set is switched to the long wave band, because less capacity is required on the long wave band than on the medium wavelengths. The ganging adjustments may need slight alteration after the addition of this fixed reaction arrangement.

Mains Aerial

For those situated within ten miles of the local transmitter a mains or indoor aerial may be tried if an outdoor aerial is not already erected. A mains aerial is obtained by connecting one side of the mains plug to the aerial terminal of the set. It is advisable to connect a ·001 mfd. condenser in series with the mains and aerial terminal connection, so as not to rely on the pre-set condenser taking the full mains voltage. Each pole of the mains should be tried separately, because one side will give better results than the other. If ganging is adjusted with mains aerial connection it may require resetting if the set is changed over to an outdoor aerial.

The Cabinet

A design for a plain cabinet is shown in Fig. 1. The lid is hinged so as to permit access to the adjustments and the valves after the set has been fixed in the cabinet. If a back is fitted to the cabinet, large holes should be drilled in it to provide some ventilation. Failure to ventilate a mains set will result in undue heating of the mains transformer and the valves.

The height of the cabinet will be at least 12 inches. Below the baseboard $4\frac{1}{2}$ inches is required to clear the components. Above the baseboard 7 inches gives ample clearance, but more than this will prevent the heat of the valves from warping the lid.

Gramophone Pick-up Connections

Fig. 10 shows how the detector valve circuit is altered to use the set for gramophone reproduction. The components required are a two-way switch, a 4 mfd. condenser, 200-volt working and a 300-ohm Erie resistance. A volume control potentiometer of 100,000 ohms will be required in addition if it is not self-contained with the pick-up. If the change-over switch is mounted on the panel it is advisable to screen the wiring. This wiring will affect the ganging slightly. so that these adjustments must be made subsequent to wiring the switch. The practical differences in the detector wiring are as follows :—

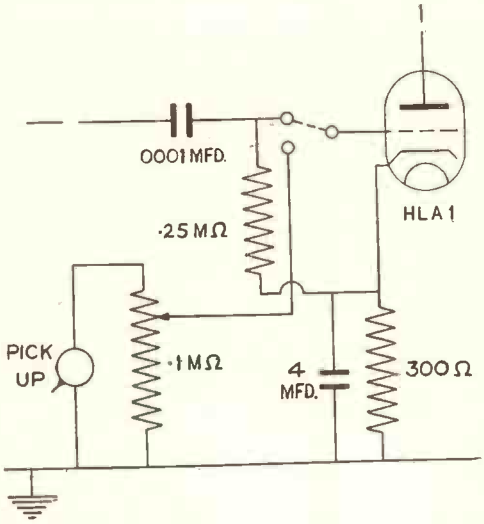


Fig. 10.—The Detector Circuit Modifications for Gramophone Pick-up which are described in the Text.

Connect the grid leak between the back terminal of the ·0001 mfd. grid condenser and the valve cathode tag. Connect the 300 ohm bias resistance in place of the short earth wire joining the cathode to coil base. The arm of the radiogram switch is connected to the valve grid terminal. The two contacts of the switch are respectively connected to one pick-up terminal and the back terminal of the ·0001 mfd. grid condenser. The wire between the latter terminal and the grid must be omitted. The other terminal of the pick-up is earthed. It may be found advisable to earth the arm of the pick-up. Usually a third terminal for this is provided on the pick-up base.

CRACKLE CAUSED BY A FAULTY ANODE RESISTANCE

In a set in which there is a resistance-capacity coupled stage, a faulty anode resistance may be the cause of occasional crackling, after which the set goes "dead."

The set can be made to work by shorting the H.T. and "Plate" terminals, after which the reception is satisfactory for a time, although the trouble eventually recurs. Substitution of a transformer for the resistance-capacity coupling unit effects a complete cure, but it may be desired to retain the resistance-capacity stage if possible.

The fault is probably due to an intermittent break in the continuity of the anode resistance. Probably the disconnection is at the junction with the resistance and the terminal, and when cold makes fairly good contact. When, however, the unit has been in circuit for some time, the expansion due to heat causes the open circuit. A permanent cure will probably result by substituting a new resistance, retaining the existing unit for the sake of the condenser and grid leak.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XIV.—A SURVEY OF MODERN VALVES

WITH the arrangement for testing valves described in the previous article it is possible to measure the various values dependent upon each other and plot these values in the form of the so-called *valve characteristic curve* or a series of such curves.

Take, for instance, the Cossor three-electrode detector valve, type 210, which is a 2-volt valve (2 volts are required across the filament). This is a battery valve used for detecting purposes. The makers give the following particulars:—

Filament voltage .	2 volts.
Filament current .	0·1 amperes.
Impedance . .	13,000 ohms.
Amplification factor .	15
Mutual conductance .	1·15 ma/v.
Maximum anode voltage . . .	150 volts.

They also add:—

Normal anode working voltage:	
for grid-leak rectification . . .	50 to 90 volts.
for anode-bend rectification . . .	150 volts.

Anode Current/Grid Volts Curves

In Fig. 1 is given a series of curves showing the relation between the anode current in milliamperes and the grid volts. There are four curves, each curve for a different anode voltage. You will remember that the anode current depends, with a given filament temperature, in other words, with a constant filament current, upon two things—the anode voltage and the grid voltage. Let us take the curve on the right which is plotted for an anode voltage of 75 volts, as indicated by the inscription at the side of the curve of Va 75 (voltage anode 75). From this curve we can see at a glance that when the grid voltage is — 4 volts the anode current is zero. At — 2 volts on the grid the current is just a little below 1 milliampere. At zero volts on the grid it is about 2·4 milliamperes, and is apparently increasing with the increase of the positive voltage on the grid.

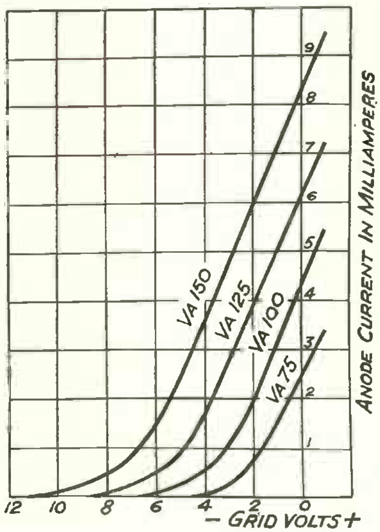


Fig. 1.—CURVES SHOWING THE RELATION BETWEEN THE ANODE CURRENT IN MILLIAMPERES AND THE GRID VOLTS OF A COSSOR TYPE 210 DET.

The second curve, at 100 volts on the anode, shows that if the grid voltage is pushed a little beyond — 6 volts the anode current will become zero. It is 2 milliamperes at — 2 volts on the grid, about 4·25 milliamperes at zero grid volts and will increase as the grid voltage becomes more and more positive.

The last curve on the left shows that with an anode voltage of 150 volts and — 2 volts on the grid the current becomes nearly 6 milliamperes and is over 8 milliamperes at zero grid volts.

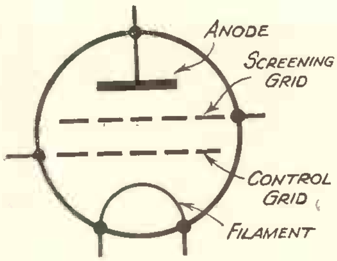


Fig. 2.—A SCREENED-GRID VALVE.

This valve with four electrodes instead of three, has an extra grid called the screening-grid.

Useful Definitions

The usefulness of such curves is quite apparent, as they convey a great deal of information about the performance of the valve at a glance. In the technical data given by the makers there is a number of terms which may not be quite clear to the novice and, for this reason, we shall state here a number of definitions which may be useful.

Anode resistance is the ratio of anode voltage to the corresponding anode current at a given grid voltage. Thus, if at an anode voltage of 100 volts and grid voltage of − 2 volts the anode current is 2 milliamperes, then the anode resistance is $\frac{100}{0{\cdot}002}$ or 50,000 ohms.

Anode impedance is a term used from the point of view of opposition to alternating current and is measured by the ratio of a small change in anode voltage to a corresponding change in anode current at a given grid voltage. Suppose that for a change in anode volts of 2 volts the current at a given grid voltage will increase by a 0·5 of a milliampere, then the anode impedance is $\frac{2}{0{\cdot}0005}$ or $\frac{20000}{5}$, *i.e.*, 4,000 ohms.

Grid resistance is the ratio of grid voltage to the corresponding grid current at a given anode voltage. The grid current can be measured by the method indicated in the previous article.

Grid impedance is the ratio of small change in grid voltage to a corresponding small change in grid current at a fixed anode voltage.

Conductance is the reverse of resistance. Mathematically it is called the reciprocal of resistance. In mathematics, a reciprocal of 5 is $\frac{1}{5}$; a reciprocal of 10 is $\frac{1}{10}$. Therefore

$$\text{Conductance is } \frac{1}{\text{resistance}}.$$

Thus, if you know the resistance you can determine the conductance by merely dividing 1 by the resistance.

Anode conductance is the reciprocal of anode resistance, or anode impedance.

Grid conductance is the reciprocal of grid resistance or impedance.

Mutual Conductance.—This is the ratio of small change in anode current to the corresponding small change in grid voltage at a constant anode voltage.

Amplification factor is the product of mutual conductance and anode impedance.

Strictly speaking, the term amplification factor should be applied to an amplifying device as a whole, as it is the ratio of voltage, current or power at the output end to the voltage, current or power at the input end.

Three-electrode Valve in a High-frequency Circuit

When a three-electrode valve is placed in the high-frequency circuit there is an *overswinging of potentials* and accompanying distortion of signals owing to the interaction between the anode and the grid. The grid of the H.F. valve is connected directly to the aerial circuit and is made alternately positive and negative by the

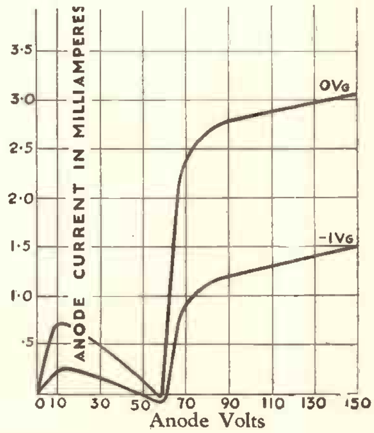


Fig. 3.—CHARACTERISTIC CURVES OF A COSSOR TYPE 220 SCREENED-GRID VALVE.

aerial potentials, these alternations taking place a million or more times each second.

What Happens when the Grid is made Positive

When the grid is made positive it means that the aerial is robbing it of its electrons and unbalancing its protons. The unbalanced protons will attract the electrons passing between the filament and the anode, increase their numbers, so that more electrons will reach the plate than before. Owing to this increased invasion of electrons, the anode will rapidly balance many of its protons and will thus become *less positive* than it should be.

Attractive Power of the Anode Reduced

This will reduce the attractive power of the anode, fewer electrons will start to arrive from the filament and in addition to this the accumulated electrons on the anode will repel electrons from the grid, making it poorer still in electrons and therefore still more positive. This will make it more positive than the aerial could make it.

Thus the grid potential and the anode potential are overswinging their intended values and the valve is not working strictly in accordance with the intended signals. A similar state of affairs will prevail during the negative half cycle. Unless precautions are taken, the valve begins to oscillate, which means strong distortion.

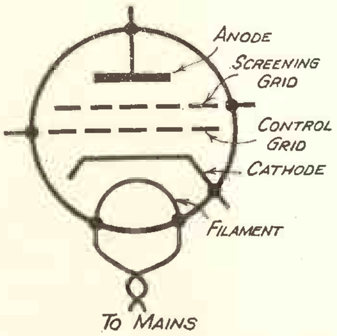


Fig. 5.—DETAILS OF THE CONSTRUCTION OF A MAINS VALVE.

The filament is used merely as a heater increasing the temperature of the cathode.

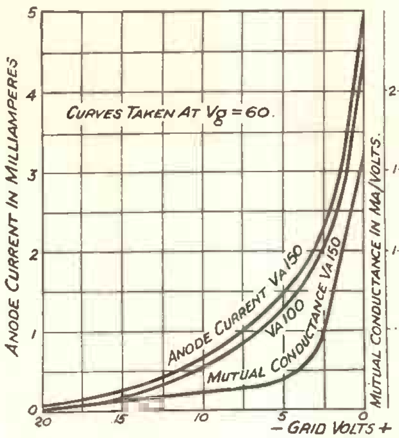


Fig. 4.—CHARACTERISTIC CURVES OF THE COSSOR VARIABLE MU SCREENED-GRID VALVE TYPE 220 V.S.G.

Balancing Condensers

In the past this tendency to overswing potentials has been counteracted to some extent by the introduction into the circuit of balancing condensers which in charging and discharging compensated for the interaction between the grid and the anode.

The Screened-grid Valve

In modern practice a different type of valve to the three-electrode is used, called the *screened-grid valve.* This valve, with four electrodes instead of three, has an extra grid, called the *screening grid* (Fig 2). The screening grid is made of fine metal gauze so that it does not interfere to any great extent with the electrons passing from the filament to the anode. When the aerial makes the control grid alternately positive and negative the interaction now takes place not between the control grid and the anode but between the control grid and the screening grid. The latter is usually connected to earth through a large condenser so that it promptly compensates any overswinging of potentials at the expense of earth.

Why Greater Amplification can be obtained with a Screened-grid Valve

The anode can now attract its electrons undisturbed and the current in the anode circuit is varying more strictly in accordance with the variations of aerial potentials than in the case of a three-electrode valve. The screening grid is given half the anode positive potential and is thus made to act as an auxiliary anode, considerably increasing the flow of electrons from the filament to the anode. In this manner it is possible to obtain with a screened-grid valve a much larger degree of amplification than with an ordinary three-electrode valve.

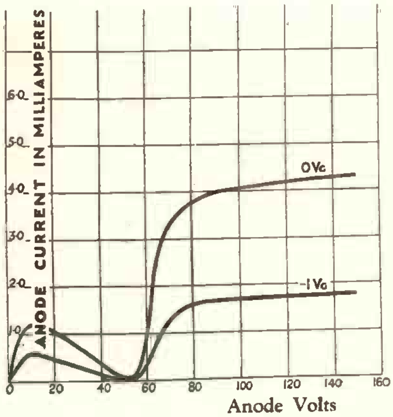


Fig. 6.—Characteristic Curves of a Mains Screened-grid Valve.

The data relates to a Cossor type 41 M.S.G. (indirectly heated).

Characteristics of a Screened-grid Valve

Let us consider the Cossor, type 220, screened-grid valve, the characteristic of which is given in Fig. 3. This characteristic shows the relation between the anode current and anode volts with a given grid voltage. Note the peculiar shape of the curve. We shall discuss this latter later in this article. The technical data of the screened-grid valve are rather interesting, especially if you compare them with those of a three-electrode valve.

- Filament voltage, 2 volts.
- Filament current, 0·2 amperes.
- Impedance, 200,000 ohms.
- Amplification factor, 320.
- Mutual conductance, 1·6 ma./v.
- Inter-electrode capacity of the order of 0·001 micro-micro-farads.
- Maximum anode voltage, 150 volts.
- Anode current at 150 volts, with 1·5 volts on the grid, 7 m.a.

at a positive voltage on the screening grid of 60 to 80 volts.

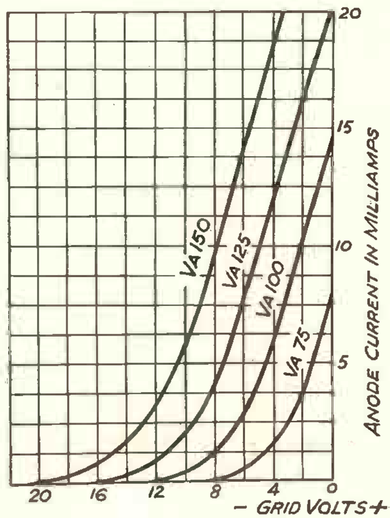


Fig. 7.—Characteristic Curves of a Cossor Type 215 P. Power Valve.

Variable Mu Valve

The application of the screened-grid valve in circuits has been discussed in other articles of this work, and we shall therefore deal straight away with a differently designed type of screened-grid valve called the *variable mu valve*. The reason for the existence of this particular type is that at the present moment there is a large number of stations working at all sorts of powers. With a receiver designed to work at a predetermined maximum signal input, a difficulty arises straight away in the case of close-lying powerful stations. If the quality of reception is to be preserved the volume has to be controlled somehow. There are several methods of controlling the volume of a receiver, but this can also be effected with the help of the variable mu valve, and automatic grid bias.

Mutual Conductance

Now, as we already know, the mutual conductance of a valve is the ratio of a small change in the value of the anode current to the corresponding small change in the value of the grid voltage, the anode voltage and the filament current remaining constant. This mutual conductance is designated by μ (mu).

Effect of Varying Mutual Conductance

As it happens, the amplification due to a screened-grid valve is roughly proportional to the mutual conductance of the valve, so that if mutual conductance is varied the amplification and therefore the volume will vary. As the grid voltage is varied the mutual conductance will vary, and therefore with the change in grid voltage we shall have a change in amplification and volume. When the grid bias is diminishing the mutual conductance will be increasing; conversely, when the grid bias is increased the mutual conductance will diminish.

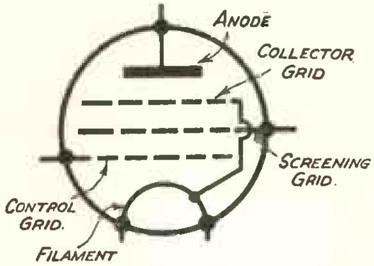


Fig. 8.—DETAILS OF THE CONSTRUCTION OF A PENTODE VALVE.

This has five electrodes, and differs from the screened-grid valve in that it has an extra grid, called the collector grid.

This means that if with a strong signal we give the grid a large negative potential, we shall reduce the mutual conductance and with it the amplification and therefore the volume of signal. On the other hand, with a weak signal we can reduce the grid bias, increase the mutual conductance and thus the amplification.

Automatic Grid Bias

The grid bias is arranged so that it acts automatically. This can be done with an ordinary screened-grid valve, but in this case we are working upon the unstable portion of the valve characteristic. With a specially designed variable mu valve the working conditions are made stable, and the whole arrangement therefore works efficiently. The variable mu valve is used in the high-frequency circuit. By the way, some authors use the letter μ to designate the amplification factor. It should be remembered, therefore, that here μ stands for mutual conductance.

The characteristic curves of the Cossor variable mu screened-grid valve, type 220 V.S.G., is given in Fig. 4. In this curve the relation between anode current and grid volts with a given anode voltage and filament current is given.

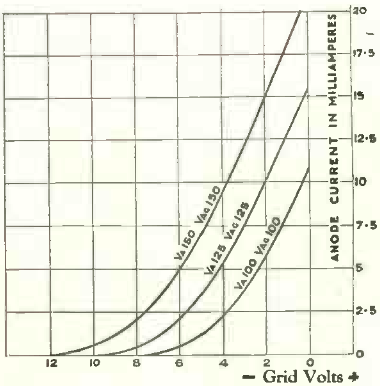


Fig. 9.—CHARACTERISTIC CURVES OF COSSOR TYPE 220 H.P.T. PENTODE VALVE.

Mains Valves

All the valves discussed above are battery valves. It is interesting to compare their performance with the so-called *mains valves*, *i.e.*, valves which obtain their anode voltage, their grid voltage and their filament voltage directly from the supply mains.

The Cathode

In the case of such valves the filament is used merely as a heater increasing the temperature of *the cathode*, which is the actual body emitting electrons. You will realise that it does not matter how the electron-emitting surface is heated, for, provided that it is heated, it will emit electrons. This is shown in Fig. 5. The filament is connected to the mains supply. A current flows through it bringing up its temperature within the required limits. The heat radiated by the hot filament is communicated to the cathode, which is coated with chemicals rich in electrons. As soon as the temperature of the cathode is sufficiently high it will start to emit electrons in the same way in which the filament of a battery valve has been emitting electrons, and the latter will pass on to the anode in the usual way.

Characteristics of a Mains Screened Valve

Here are the data and the characteristic (Fig. 6) of a mains screened-grid valve, Cossor, type 41 M.S.G. (indirectly heated). Heating filament voltage is 4 volts, and the filament current is 1 ampere. Maximum anode voltage, 200 volts. Maximum screened-grid voltage, 80 volts. Impedance, 400,000 ohms at 130 volts on the anode, 60 volts on the screened-grid and zero volts on the control grid. Amplification factor, 1,000 with the same anode and screened-grid voltages.

Mutual conductance, 2·5 milliamperes/volt at the same voltages as above. Inter-electrode capacity of the order of 0·001 micro-microfarads. Anode current with 130 volts on the anode, screened-grid volts 60, and control grid bias − 1·5 volts, 3 milliamperes. Bias resistance, 1,500 ohms.

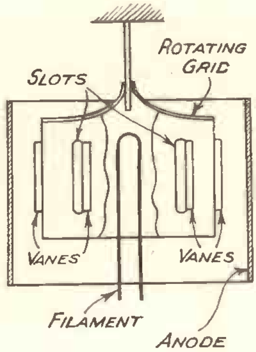


Fig. 10.—Details of the Construction of a Valve with a Rotating Grid.

The rotating grid is a metal cylinder with slots and vanes. The electrons from the filament are attracted by the grid and some of them pass through the slots, bombard the vanes, and thus repel them.

High-frequency Electric and Magnetic Fields

The screened-grid valve with its tremendous amplification brought with it additional design problems which in the past were unknown. The rapidly alternating currents in the H.F. stage bring with them high-frequency electric and magnetic fields which when making their appearance around various components and wires pass on energy to places where such energy is the last thing we want.

Screening Problems

This brought to the fore the problem of screening one component from another. Magnetic fields are isolated by surrounding their source with an iron closed shield so that the lines of force of the magnetic field, instead of spreading in air, are concentrated within the iron, which is a magnetic material. In order to isolate an electric field, any closed metallic shield connected to earth will do, provided it completely surrounds the body which is being isolated from the surrounding electric fields. It is for this reason that the screened-grid valve is placed within metallic casing, and every component is surrounded by metal or placed within a metal pot. You will find these problems being discussed elsewhere in this work.

On the low-frequency side of our receiving circuit we can use the ordinary three-electrode valves, specially designed for this stage. But as a rule, in a multi-valve receiver, such valves prove to be inadequate, as they cannot deal with the large output without being considerably overloaded and thus distorting.

Power Valves

For this reason so-called *power valves*, which are three-electrode valves, are used in the L.F. stages. There are also three-electrode valves called super-power valves which are a further development of the power valve. Many people think that a super-power valve will give louder signals on distant stations than a power valve; actually, the reverse is the case. A super-power valve will give a greater volume when handling a relatively large input, while a power valve will give greater volume when handling a moderate input.

Characteristics of a Power Valve

Fig. 7 shows a typical characteristic of a power valve. This is Cossor type 215 P, which has the following technical data :—

Filament voltage .	2 volts.
Filament current .	0·15 amperes.
Impedance . .	4,000 ohms.
Amplification factor .	9
Mutual conductance .	2·25 ma./v.
Maximum anode voltage . . .	150 volts.
Grid bias for 150 volts on the anode . .	7·5 volts.
Anode current at 150 volts on the anode with a grid voltage of − 7·5 volts .	13·75 ma.
Optimum load .	9,000 ohms.

Pentode Valve

We shall leave the question of rectifying valves for the moment, until we deal with rectification. Therefore, the last valve on our list is the so-called *pentode valve*, which has five electrodes. These five electrodes can be seen in Fig. 8. This valve differs from the screened-grid valve in that it has an extra grid, called the *collector grid*. Thus, the five electrodes are arranged as follows: the filament, around it the control grid. Around the control grid is the screening grid which fulfills the same functions as the screening grid in the screened-grid valve. Around the screening grid is the collector grid, which is connected to the filament inside the valve, and finally the anode.

Now, if you look again at the characteristic of the screened-grid valve in Fig. 3, you will see that as the anode voltage starts from zero the current through the valve starts to increase till we come to 10 volts on the anode. After that, as the anode voltage is increased the anode current rapidly diminishes till it drops to zero at about 60 volts. From this point it increases rapidly and becomes stable between 90 and 150 volts on the anode.

The curve, as you see, makes a kink. It would be hopeless to try and work the valve at voltages at which the kink in the value of the current occurs, and therefore we work the screened-grid valve on the H.F. side of the circuit with such a value of anode voltage and grid voltages that we are far away from the unstable part of the valve characteristic.

This kink in the value of anode current is due to a secondary effect which consists in the anode firing off its own electrons which are being knocked out of it by the filament electrons arriving at great speed under the double pull of the anode and the screening grid. It is this double pull that is responsible for this state of affairs. This sort of thing cannot happen in an ordinary three-electrode valve, as there is no screening grid to help the anode.

Now this behaviour on the part of the screened-grid valve in the H.F. circuit, where the current is smaller and the kink is concentrated over a small range of voltages, does not matter, as we can always find a stable portion of the characteristic to work on.

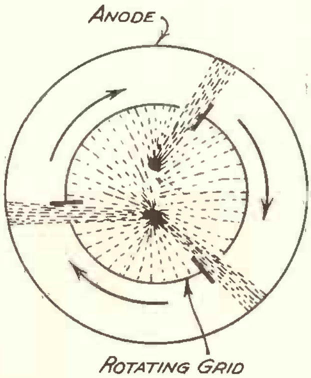


Fig. 11.—Showing how the Electrons from the Filament are attracted by the Grid and pass through the Slots.

Why the Third Grid is Introduced

In the output valve of a receiver, in the low-frequency amplifying circuit, where the stream of electrons from the filament to the anode is much larger, this is a serious matter and has to be remedied. In order to avoid the opposition stream of electrons flying from the anode towards the filament and thus reducing the flow of electrons from the filament to the anode (remember that electrons repel each other), a third grid, the collector grid, is introduced, which collects the secondary electrons from the anode and conveys them to earth. In this manner we still have a double pull upon the filament electrons and therefore a large anode current, but we avoid any interference with the main electrons stream.

Characteristics of a Pentode Valve

In Fig. 9 the characteristic curves of a pentode valve are given. This is Cossor type 220 H.P.T. Its technical data are as follows:—

Filament voltage .	2 volts.
Filament current .	0·2 amperes.
Mutual conductance .	2·5 ma./v.
Maximum anode voltage . . .	150 volts.
Maximum screened-grid voltage . .	150 volts.
Grid bias for maximum voltages as above .	4·5 volts.
Anode current with voltages as above .	8 ma.

The pentode valve is used, as a rule, as a single L.F. stage, as it is easily overloaded. It is eminently suitable for circuits with small input. When it is used with a moving-coil loud speaker it should be shunted by a ·01 mfd. condenser in series with a 10,000 ohms resistance.

It is very interesting to test the behaviour of the various types of valves as detectors. The pentode gives some remarkable results.

Rotating Grid

There is being developed

in America a valve with a rotating grid. This rotating grid is a metal cylinder with slots and vanes, as can be seen from Figs. 10 and 11. The electrons from the filament are attracted by the grid and some of them pass through the slots, bombard the vanes and thus repel them so that the latter are bound to rotate, entraining the grid with them. In this manner the valve acts akin to a turbine and is referred to as the electronic turbine. The anode is also a metal cylinder.

It is claimed that the rotating grid does not interfere with the flow of electrons from the filament to the anode, and the whole arrangement will work as an ordinary three-electrode valve in a wireless receiver. This is only one of its functions. The rotating grid valve will act as a commutator, a switch, an interrupter or a converter. It is also used as an electronic motor in electric clocks. It can also be used in television. No doubt it will be developed in the near future, and the mechanically-inclined listeners will have the satisfaction of seeing "something going round" in a receiver.

QUESTIONS AND ANSWERS

What is the Difference between Anode Resistance and Anode Impedance ?

By anode resistance is meant the ratio of anode voltage to the corresponding anode current at a given grid voltage. Anode impedance, however, is a term used from the point of view of opposition to alternating current. It is measured by the ratio of a small change in anode voltage to a corresponding change in anode current at a given grid voltage.

What is the Difference between Grid Resistance and Grid Impedance ?

The explanation of these two terms is similar to that of the previous question. Whereas grid resistance is the ratio of grid voltage to the corresponding grid current at a given anode voltage, grid impedance is the ratio of small change in grid voltage to a corresponding small change in grid current at a fixed anode voltage.

What is Meant by Conductance ?

Conductance means the reverse of resistance, or, as it is called mathematically, the reciprocal of resistance. If the resistance is known, the conductance can be determined by merely dividing 1 by the resistance. Thus, anode conductance is the reciprocal of anode resistance or anode impedance, and grid conductance is the reciprocal of grid resistance or grid impedance.

What is Mutual Conductance ?

Mutual conductance is a term used to express the ratio of small change in anode current to the corresponding small change in grid voltage at a constant anode voltage.

What is Meant by Amplification Factor ?

Amplification factor is the ratio of voltage, current or power at the output end, to the voltage, current or power at the input end. For a single valve, the amplification factor is the product of mutual conductance and anode impedance.

LOW-FREQUENCY TRANSFORMERS

By FRANK PRESTON, F.R.A.

Fig. 1.—SOME EXAMPLES OF LOW-FREQUENCY TRANSFORMERS.

From left to right: Varley " Reactone " Tone Control Transformer (with variable resistance); Bulgin " Transcoupler " Resistance-Fed Transformer; R.I. " Hypermu " L.F. Transformer; Lotus Type 3 Audio-Transformer; Lissen " Hypernik " Transformer with Tone Control Unit and Potentiometer; Front, Lotus " No. 1 " Transformer.

A LOW-FREQUENCY transformer is a component used to couple together two amplifying valves. Its object is to provide a step-up or increase in voltage. The transformer consists of two windings, a primary and a secondary, arranged on a core of ferrous material. The primary has fewer turns than the secondary and the proportion between the numbers of primary and secondary turns is referred to as the transformer ratio.

Ratio

For instance, if there were 10,000 turns (a fairly average number) on the primary and 40,000 on the secondary, the transformer would be said to have a 4 : 1 ratio. Theoretically the voltage step-up afforded is equal to the ratio, so that if a voltage (of audio-frequency current) of 2 were applied to the primary winding, 8 volts would be developed across the ends of the secondary.

In practice the actual voltage step-up ratio is not quite equal to the turns ratio because of the resistance of the windings, imperfections of the core and so on.

Choosing a Transformer

A skeleton circuit of a typical transformer-coupled amplifier is given in Fig. 2.

When buying a transformer for such a circuit one should always obtain a component which has a high primary inductance when carrying the necessary amount of anode current.

Parallel Feed

A good method of connecting a transformer is in the manner shown in Fig. 4. In this case the resistance " R " carries the full D.C. anode current of V.1 and the transformer has thus to deal only with the audio-frequency currents which are passed on to it by the coupling condenser " C." This system of transformer connection is referred to a parallel feed or resistance feed due to the fact that the primary winding

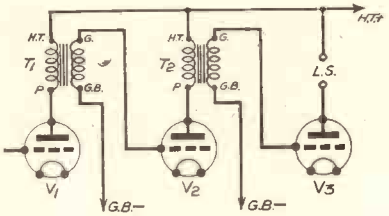


Fig. 2.—Skeleton Circuit of a 2-stage Transformer Coupled Amplifier.

is virtually in parallel with the resistance, and the anode current is fed through the latter instead of through the transformer.

Since the primary winding of the transformer has not to deal with the steady anode current of V.1 its inductance maintains a maximum value and there is no possibility of the core becoming saturated. In consequence, quite a small and inexpensive transformer can be made to give satisfactory response to the very lowest frequencies.

Value of Resistance and Condenser

The value of " R " (in ohms) must be about twice the impedance of V.1 and the capacity of " C " must be large enough to provide an easy path for all audio-frequency currents ; a capacity of from ·25 to 1 microfarad is generally employed.

With this form of coupling the actual step-up ratio of the transformer is very nearly equal to the turns ratio.

L.F. Coupling Units

In order to simplify the use of resistance feed a few L.F. coupling units are now available which combine a transformer, resistance and condenser. The best known of these are the Bulgin " Transcoupler," Benjamin " Transfeeda," and the R.I. " Parafeed." In each case the resistance has a total value of 50,000 ohms but is tapped at 30,000 ohms so that either value can be employed at will. The lower value is suitable for use after valves having an impedance of some 15,000 ohms or less, and the higher value is appropriate to all valves up to 25,000 ohms.

Simple De-coupling

A practical point which is worth remembering is that when the 30,000 ohm portion only of the resistance is used for its legitimate purpose the remaining (20,000 ohms) part can be used for decoupling by connecting a 2 mfd. condenser between the tapping and earth. Fig. 5 will make this explanation quite clear.

Alternative Ratios from same Transformer

It is interesting to notice that when using an ordinary transformer in a parallel-feed circuit a number of alternative step-up ratios can be obtained by altering the connections to those given in Fig. 6. The connections shown at (*a*) are those already described and the ratio obtained is the nominal one ; for purposes of comparison let us call it 4 : 1. By altering the connections to those shown at (*b*), that is by putting primary and secondary in series and joining one side of " C " to the junction, the ratio becomes 5 : 1, or that of the total number of turns on both windings to the number of turns on the primary. When the connections are changed to those shown at (*c*) the ratio is reduced to 1 : 1. Although a transformer is employed, the methods of coupling shown at (*b*) and (*c*) are known as " auto-choke " because, since the windings are in series, the transformer really acts as a tapped choke.

Tone Control Transformers

In a previous article on " Tuning Coils " it was explained that when very selective tuning circuits are employed they cause a definite loss of high-note amplification. To counteract this we must so adjust our L.F. circuits that they will give additional amplification to the higher notes, and as a

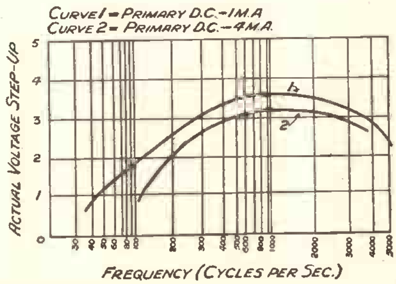


Fig. 3.—Performance Curves for a Typical Medium-priced Transformer when passing different Values of Primary D.C.

result make all notes of equal intensity by the time they reach the loud speaker.

Various forms of correction devices can be employed for this purpose, but the simplest is the tone control transformer. As a matter of fact we cannot actually give extra amplification to high notes, but we can, and do, achieve the equivalent result by curtailing low-note amplification.

This is done by using a transformer fitted with a small L.F. choke, which can be connected in parallel with the primary winding through a variable resistance. The circuit is shown in Fig. 7, where the transformer referred to is the Varley "Reactone." The tone-control choke and variable resistance are themselves in series and the two are put in parallel with the primary winding. The choke has the effect of reducing the primary inductance and so lessening its response to low frequencies. As the amount of resistance in circuit is increased the effect of the choke is reduced and so low-note amplification can be brought up to its normal level if desired.

High- and Low-Note Emphasis

The type of tone control transformer just described can only operate in the desired manner when the rest of the circuit is designed to emphasise low-note response. Its use is therefore limited and it would not confer any advantages to a flatly tuned set or one fitted with band-pass tuning. Similarly, it would probably be of little use if the set were used as an amplifier with a pick-up.

As a matter of fact, additional low-note amplification would most probably be

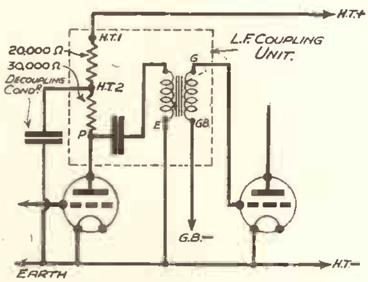


Fig. 5.—Using a portion of the Resistance in a Low-frequency Coupling Unit for De-coupling the Anode Circuit of the preceding Valve.

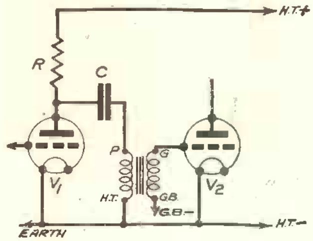


Fig. 4.—A Low-frequency Transformer used in a Resistance-feed, or Parallel-feed Circuit.

required in the latter cases and consequently the transformer should give just the opposite effect to the type described.

Suppressing either High or Low Notes at Will

For this reason another type of tone-control transformer has recently become available with which either low or high notes can be suppressed at will. This, of course, gives the equivalent effect to providing additional high- or low-note amplification. The best known transformer of this kind is the "Multitone," but in addition there is the Lissen Tone Control Unit which is made to fit on to the Lissen "Hypernik" transformer, and which can, in fact, be connected up to any other transformer.

The circuit arrangement of the "Multitone" transformer, and of the Lissen combined tone-control unit and transformer, is the same as is shown in Fig. 8. It will be seen that besides the transformer and L.F. choke a fixed condenser is also provided. One side of both the choke and condenser are joined to one end of the transformer primary and the other sides are connected one to each end of a high-resistance (·25 megohm upwards) potentiometer of which the slider is connected to the other end of the primary.

Effect of the Potentiometer

When the potentiometer slider is moved to the end marked "1" the choke is put in parallel with the transformer primary and in consequence the inductance of the plate circuit is considerably reduced. As a result the lower frequencies can leak away across it and so escape amplification. On the other hand, when the potentio-

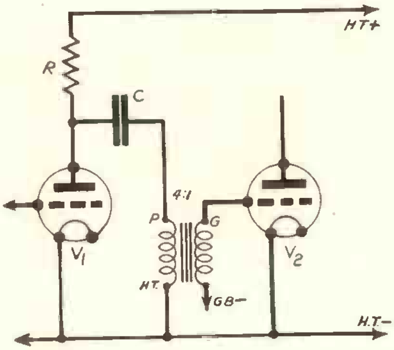


Fig. 6A.—How to Connect a Low-frequency Transformer on the Resistance-feed System.

This circuit gives a 4 to 1 step-up ratio.

meter slider is moved to the end marked " 2 " the condenser is put in parallel with the primary, and this permits the higher frequencies to leak away. It will be clear that by adjusting the potentiometer between its two limits the degree of high-note or low-note loss can be varied at will.

If desired, any type of tone control transformer can be connected on the parallel feed system as shown in Fig. 4. As a matter of fact, the three referred to are all capable of carrying a primary current up to 4 milliamps without fear of core saturation, and so it will seldom be necessary to resistance-feed them. If any low-note loss were to result from the passage of a fairly high primary current it could easily be compensated for by adjustment of the control.

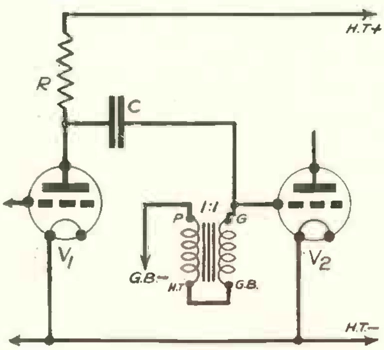


Fig. 6C.—How to Connect a Low-frequency Transformer on the Resistance-feed System.

This circuit gives a 1 to 1 step-up ratio.

Push-Pull Transformers

Our study of L.F. transformers would be incomplete if we were not to consider those specially designed for push-pull amplifiers. A circuit diagram of an amplifier using push-pull is given in Fig. 9, whilst Fig. 10 shows a simple push-pull amplifier.

Two transformers, one input and one output, are used. The input transformer has a primary winding just like that of any other L.F. transformer, but the secondary winding is divided into two halves each of which feeds one valve. The centre tapping takes the grid bias supply for both valves.

The output transformer is the opposite

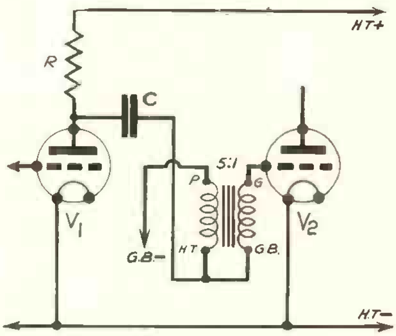


Fig. 6B.—How to Connect a Low-frequency Transformer on the Resistance-feed System.

This circuit gives a 5 to 1 step-up ratio.

of the input since its primary winding is divided into two halves which " collect " the output from the two valves. The secondary winding is a single one, but is generally supplied with two or three tappings so that different ratios can be obtained for the purpose of matching the loud speaker to the valves.

Push-pull input transformers are generally a good deal larger (physically) than ordinary L.F. transformers, because being used after other low-frequency valves their primary windings have to carry a comparatively large D.C. current. At the same time the impedance of the preceding L.F. valve is fairly low and in consequence a low inductance primary winding is permissible. The best-known push-pull transformers are the Varley and Ferranti, and in each case the primary winding of the input transformer will carry up to 10 milliamps, and at that figure shows an inductance of just under 30 henries.

When the preceding valve takes an anode current in excess of 10 milliamps the transformer can be resistance-fed in just the same way as any other type.

Use Matched Valves

In building a push-pull amplifier the two valves used in push-pull should be obtained as a matched pair; if they are not identical in their characteristics a certain amount of instability is likely to occur. As an additional safeguard against the latter trouble it is advisable to insert a

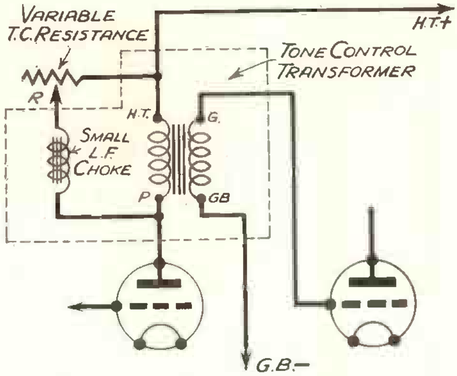


Fig. 7.—CONNECTIONS FOR A TONE CONTROL TRANSFORMER USED FOR SUPPRESSING LOW-NOTE AMPLIFICATION.

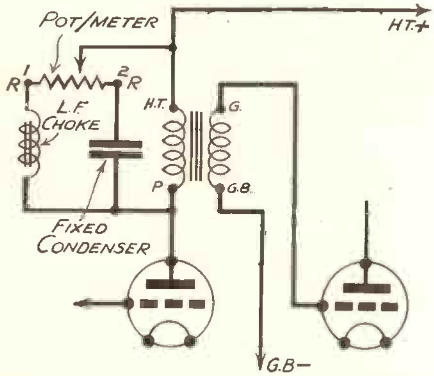


Fig. 8.—A TONE CONTROL TRANSFORMER OF THE TYPE SHOWN HERE CAN BE USED TO REDUCE EITHER HIGH- OR LOW-NOTE AMPLIFICATION.

100,000 ohm decoupling resistance in series with the grid lead to each valve as shown in Fig. 9.

Advantages of Push-Pull

The push-pull system of amplification has numerous advantages over others when a very large volume is required and at the same time the available high-tension supply is limited to, say, 200 volts. Stated briefly the advantages are as follows :—

(1) Two small power valves can be employed to give an output equal to a single one of twice the power handling capacity.

(2) The output transformer is more effective than in other cases because there is no appreciable magnetisation of the core by D.C. current—due to the fact that the magnetisation that would be caused by one half of the primary winding is cancelled out by that caused by the other half.

(3) As a result of (2) the size and cost of the output transformer can be kept down even though very large power valves are in use.

(4) Most forms of distortion which would occur in a single valve are cancelled out by the other.

(5) Ordinary directly-heated valves can be used and the filaments heated by A.C. derived from a transformer winding; the A.C. ripple is cancelled out. The use of A.C. filament current results in longer valve life.

Arrangement of Transformers

When building a receiver the disposition of the transformers employed should receive careful attention. In the first place they must be kept well away from the tuning circuits to avoid "pick-up" of H.F. currents from the coils.

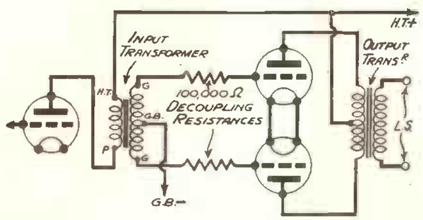


Fig. 9.—SKELETON CIRCUIT OF A PUSH-PULL AMPLIFIER.

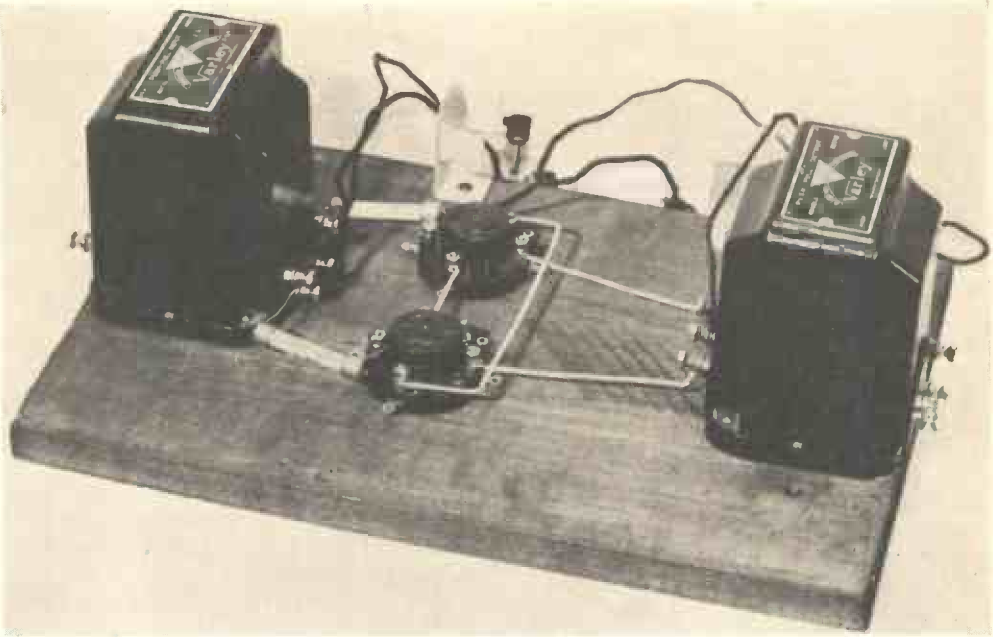


Fig. 10.—A SIMPLE PUSH-PULL AMPLIFIER.

The Input Transformer is on the left of the baseboard, and the output transformer on the right.

Earth the Core

To ensure freedom from L.F. instability the transformers should be kept a reasonable distance apart and they should be so arranged that their cores are at right angles. In this respect it is also helpful to earth the iron cores.

High or Low Ratio ?

When using only a single stage L.F. amplifier it is generally best to choose a transformer with a high ratio (up to 7 : 1 or so) provided that its other characteristics are suitable for the circuit. But a lower ratio component with a high primary inductance will almost invariably give more amplification, as well as better quality, than a transformer with a high ratio and a low primary inductance. I will repeat what I have said before, that high primary inductance at the working current is more important than anything else.

Low Ratio Multi-Stage Amplifiers

In an amplifier having two or more transformer coupled stages it is best to use low ratio transformers unless one is prepared to take elaborate precautions in regard to de-coupling anode and grid circuits. As a general rule a ratio of from 1 : 1 to 2½ : 1 is most satisfactory when more than two stages are employed, but it is safe to go up to 3½ : 1 in a two-stage amplifier.

Curing Instability

If instability is experienced after taking the precautions mentioned, a cure can often be effected by reversing the secondary connections to the last transformer or the primary connections to the first ; the reversal stops L.F. oscillation in the same way as reversing the leads to a reaction coil stops H.F. oscillation.

Another remedy for L.F. instability is to connect a quarter megohm grid leak across the secondary winding of the last transformer. This also has the effect of preventing " shrillness," or over-emphasis of high notes.

PROBLEMS OF MOTOR CAR RECEIVER DESIGN

By EDWARD W. HOBBS, A.I.N.A.

WIRELESS receivers for use on motor cars call for special treatment, not only as regards the design and construction of the set, but particularly the details of its installation in the car.

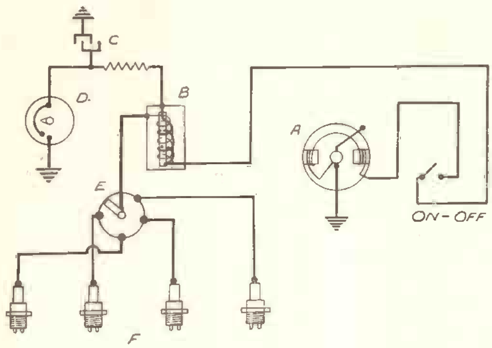


Fig. 1.—The Essential Components of an Ignition System.

Compare this with Fig. 2, where the same components are expressed as a theoretical circuit of a spark transmitter.

Inherent Difficulties

In the first place the ignition system of the car, although remarkably efficient for its purpose, is at the same time a tolerably effective spark transmitter, and directly affects the receiver.

The essentials of a modern car ignition system are shown in schematic form in Fig. 1, where A is the generator that supplies current to the ignition coil B, which, of course, is an induction coil or "spark" coil; C is a condenser to deal with certain local current surges; D is the contact breaker driven by the engine, while E is the distributor or rotating switch which directs the high-tension current from the secondary of the ignition coil to each of the four spark plugs F in sequence.

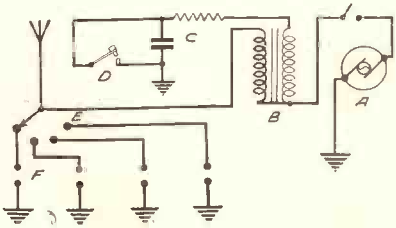


Fig. 2.—Ignition System as a Transmitter.

The components shown in Fig. 1 are here interpreted in the familiar symbolism of theoretical circuits, to show how they act as a spark transmitter.

Ignition System a Transmitter

If these same components were used as a spark transmitter, the circuit would look very much like Fig. 2, where the circuit breaker D appears as a Morse key, and the spark plugs F as four alternative transmitting spark gaps with the high-tension wiring acting as an aerial and the metal of the engine as the earth lead.

Every time a spark occurs in the engine, the high-tension wires and part of the engine become highly charged, and do in fact emit radiations akin to those of a spark transmitter, and are picked up and amplified by the receiver. Not only so, but each spark plug has a wiring system of its own, all being of different length, hence the "signals" are on different wavelengths. What may be called the periodicity of the signals varies with engine speed, but is always within audible frequencies.

Variable Interference

Ignition interference varies in magnitude and intensity with different makes of car, and even in different cars of the same make and type, due to minor mechanical variations in width of spark gap, length of wiring, and so forth.

The positions of the components, the proximity of metal panelling which may act as a shield or otherwise, and passing cars, all [add

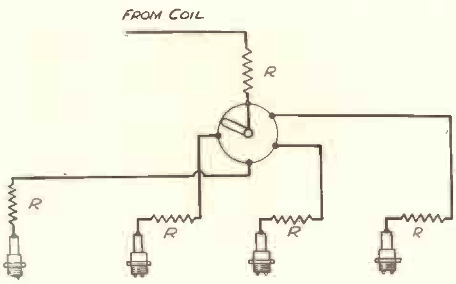


Fig. 3.—SPARK SUPPRESSOR.

A wire wound resistance R of about 25,000 ohms close to each spark plug assists in preventing interference and a similar resistance is used in the central lead to the distributor.

their quota to the general causes of interference by direct radiation.

How to Cure Ignition Interference

The best solution of the ignition interference problem is to neutralise the H.F. radiation of the car system. In practice this is being tackled on the lines of "de-coupling" the offending units; by "suppressing" the spark plugs; and by shielding the components.

Spark Suppressors

Much of the trouble from the spark plugs can be overcome by inserting a good grade resistance close up to each plug. The resistance should be wire-wound and have a resistance value of at least 25,000 ohms; it is inserted in series with the H.T. lead as shown in Fig. 3.

Another similar resistance should be inserted in the main lead to the distributor to cut out the effects of the rotor which often sparks as the circuits are made and broken.

Best Value for Resistances

The best value for these resistances must be found by trial, if too high; they may affect the running of the engine, especially when idling or running light; on the other hand, their choking properties are of little effect if the value is too low. It will generally be found that a value of 25,000 ohms is the best average. The colour of the spark is a good indication of the effect of the added resistance; if the spark is very yellow, it shows that the resistance is too low; best results are obtained when the spark is practically white.

De-coupling Methods

The next step is to "de-couple" any component that is causing trouble; for instance, a 1 mfd. fixed condenser of good quality as used on "mains" receivers may usefully be connected across the battery or generator side of the ignition coil and earth, as at C in Fig. 4, and similar condensers can be shunted across the circuit breaker, spark plugs and other components.

It will, of course, be appreciated that the metal frame and all metal parts of the car are used as the common "earth" of the electrical system generally, hence a metal car body is ostensibly earthed. If, however, there are any loose panels or other metal parts not firmly secured they become charged at varying potentials and may—and probably will—cause crackling noises. The remedy for these troubles is to bond all such loose places by soldering copper wires across the joints.

Note that acid soldering solutions should not be used—they cause trouble by setting up a form of electrolytic action; always use resin as the flux.

Shielding

A good deal of extraneous interference can be cut out by carefully shielding any of the electrical gear on the car that may be likely to cause trouble; for instance, the ignition coil, the magneto, and the generator can all be shielded with aluminium covers screwed or bolted firmly to the engine or to some metallic part of the frame.

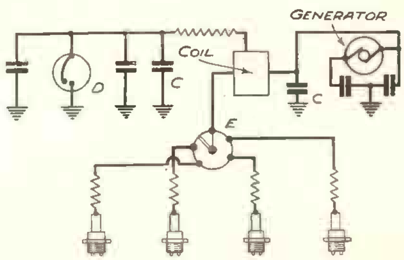


Fig. 4.—DECOUPLING ARRANGEMENTS.

Fixed condensers of about 1 mfd. capacity shunted across components and earth, as at C, help in reducing ignition interference.

Special Features of Car Set Design

Having done everything to reduce the interference from the electrical system of the car, attention must next be concentrated on some special features of the design of any set intended for use in a motor car, or of such alterations as may be required to fit a normal set for such duties.

So far as the circuit is concerned, this should be as sharply selective as possible and moderately sensitive.

Sensitivity is an advantage for the reception of weak signals, but is definitely a disadvantage when it increases the background noise from ignition and local interference.

A well-designed 4-valve "straight" receiver, with band-pass tuning, one H.F. stage with variable-Mu valve, a detector and two L.F. stages with a heterodyne whistle eliminator and automatic volume control, is probably the best all-round receiver; all tuned circuits must be carefully matched, balanced, adequately decoupled and completely screened.

Robust Construction Essential

Motor car receiving sets must be very carefully and strongly constructed; all the components must be securely fastened to obviate any chance of the vibration causing them to work loose. If the set has a wooden baseboard it should be of oak or hardwood, and all fastening screws properly and firmly driven home.

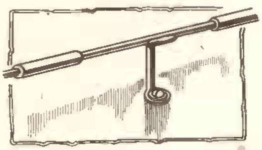


Fig. 7.—Earthed Wire Support.

Lengthy earth return wires should be supported by short wires soldered between them and bolted to the metal chassis.

If a soft wood or plywood baseboard is used the components should be bolted on with round-head brass screws and nuts, as shown in Fig. 5, the nut being drawn well into the underside of the wood.

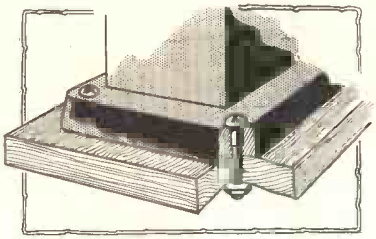


Fig. 5.—Fixing Components to Wood Base.

Use screws and nuts when fixing components to a wooden baseboard.

Fastenings to Metal Chassis

Bolts and nuts are the best fixings for components attached to a metal baseboard or chassis, but lock nuts or spring washers should be used in every case to prevent the bolts slackening. These two methods are illustrated sectionally in Fig. 6; the spring washer is quite effective if the nut is tightened properly.

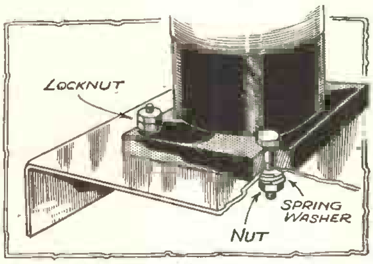


Fig. 6.—Security Fastenings.

The use of spring washers or lock nuts to prevent screws and bolts slackening under vibration are essential in car set construction.

The lock nut is a second nut which is tightened down on to the first nut and prevents the latter slackening. Always hold the first nut with a thin spanner while tightening the second nut.

Damp-Proof Windings

All coil windings should be lacquered to render them damp-resisting or moisture-proof whether they are covered by a shield or not.

All tuned circuits must be very carefully matched and balanced,; short leads are most desirable. If soldered to tags only a good resin flux should be used; if fastened by nuts, always use lock nuts,

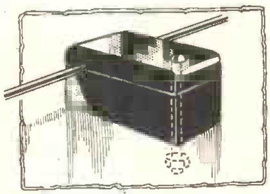


Fig. 8.—H.T. Wire Supporting Clamp.

Long wires carrying H.T. current should be supported by ebonite clamp blocks.

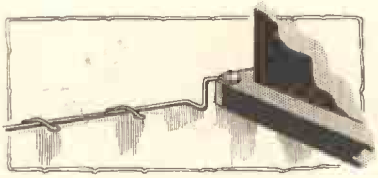


Fig. 9.—LACING A WIRE.

To prevent a long wire vibrating it can be secured with a leather thong laced through holes in the chassis.

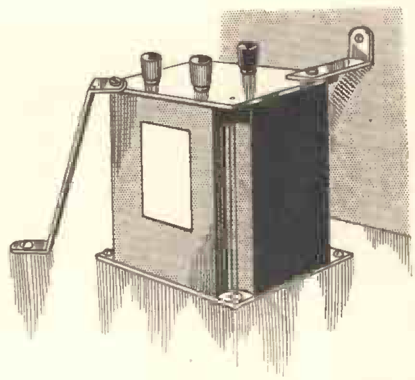


Fig. 10.—STRUTTED COMPONENTS.

Tall or heavy components should be steadied by struts, of ebonite or metal, to the base or panel.

spring washers, or take other effective steps to prevent them slackening, for example, by coating with lacquer or insulating varnish.

Long Wires to be Supported

If it is impracticable to avoid wires of 6 inches length or over, they should be supported or fastened in any convenient manner to prevent them vibrating.

Common earth return leads can be directly supported by short upright wires, as in Fig. 7, bolted to the chassis; high-tension and other wires can be securely held in ebonite clamp blocks, as in Fig. 8, consisting of a block of ebonite about ¾ inch long, ¼ inch thick, and, say, 1 inch high. A hole is drilled near one end for the wire; another hole is drilled at right angles near the opposite end for the fixing screw and nut.

A saw-cut is then made from the edge of the block to the wire hole, so that when the wire is in place the fixing screw closes the slit and grips the wire as well as holding the block in its place.

Another method for use on metal chassis is to lace the wire down by a thin leather thong, as shown in Fig. 9, put through holes drilled in the metal base.

Extra Supports for Components

Tall heavy components such as an output choke can be steadied with ebonite or metal struts, as shown in Fig. 10, either to the baseboard or the panel, as may be most convenient.

Tuning condensers must be of very stiff

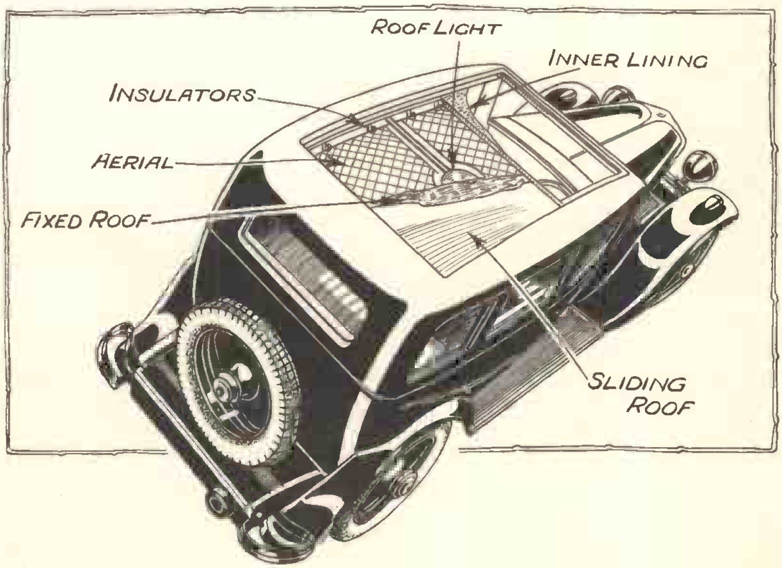


Fig. 11.—WIRE MESH ROOF AERIAL.

Copper gauze edged with copper wire and suspended on insulators fixed between outer roof covering and inner lining makes an efficient aerial.

and robust construction, the spindle should be supported at each end and the frame strutted to the base; any vibration of the condenser vanes will cause a "tremolo" effect in the loud speaker.

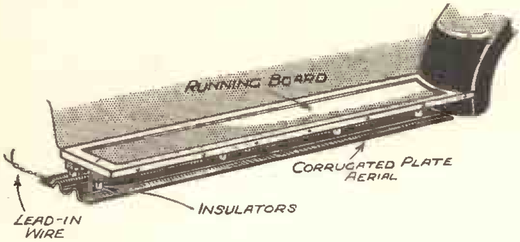


Fig. 12.—PLATE AERIAL.

A metal plate or large diameter tube attached by insulating blocks beneath the running board, for use as an aerial.

External Leads to be Cased

All external leads should be run with metal braided or encased wire, the casing or braiding properly bonded—and earthed. Proper bonding means that if the metal covering is cut at any point a piece of copper wire must be soldered across the gap to make the casing electrically continuous.

The set should be housed in a weatherproof container, and any metal casing connected directly to earth.

Best Position for Set

From the electrical interference point of view the best position for the set is fairly high up at the back of the car, but this may not accord with individual views nor suit the particular car. Another good position is behind the front seats; one of the worst is on or near the instrument board. If a separate loud speaker is used the set could be housed in a well beneath the floor boards, if the controls were brought to the top or were easily accessible by raising a hinged flap.

Aerial Equipment

The most efficient car aerial that has yet been invented is the wire mesh roof type, shown diagrammatically in Fig. 11, and fitted to the underside of the roof of a saloon car.

The aerial consists of copper gauze, strengthened at the edges with copper wire soldered in place; it is fitted under the roof about 2 inches below the underside, and should be supported on porcelain or ebonite insulators.

To fit the aerial properly the roof lining material must be removed temporarily, and in some cars it will be found that wire netting has been fitted to support the lining; in that event the wire netting must be removed and be replaced by webbing or string netting. The aerial must be kept quite clear of roof light leads and the like, which, if not already encased in metal, should be shielded and earthed. After fitting the aerial and testing the set the roof lining is replaced as before, thus concealing the aerial.

Aerial Lead-in

The best material for the lead-in wire is twin flexible electric light wire, both wires being securely soldered to the aerial and both being connected to the aerial terminal of the receiver. Place the lead-in at any point where it will be least susceptible to interference.

Plate Aerial

On open cars and some closed cars it may not be practicable to fit a roof aerial, and in that case a plate aerial fixed a few inches beneath the running boards—as in Fig. 12—is the best alternative. This may be a strip of copper or brass about 3 to 4 inches wide, and should preferably be corrugated; an alternative is a length of 2-inch diameter brass or copper tube.

It is imperative that the plate be completely and adequately insulated, very rigidly fixed, and the lead-in wire bolted and soldered to it.

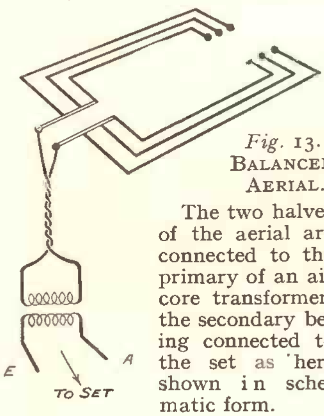


Fig. 13. BALANCED AERIAL.

The two halves of the aerial are connected to the primary of an air core transformer, the secondary being connected to the set as here shown in schematic form.

Balanced Aerial

Another type of aerial that can be used in some cases is shown schematic-ally in Fig. 13, and consists of several parallel lengths of stranded copper wire, say, 7/22 gauge, fixed on insulators, either on or under the roof of a saloon car or under the running boards. It is essential that there be the same number and disposition of wires on each side of the car. The separate groups on each side are joined together and brought to separate insulators spaced about 3 inches apart, and the whole so arranged that each system is equal in length.

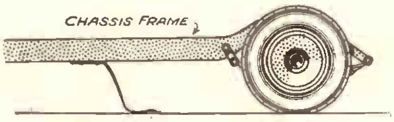


Fig. 14.—TRAILING EARTH.

A steel chain or rope attached to car frame and trailing on the ground discharges static from the metal framework of the car.

A twin flex twisted wire is used for the lead-in, one wire being connected to one aerial and the second wire to the second aerial.

The lead-in wires are then joined across an inductance, or the primary of an air core transformer; the secondary of the transformer is connected to the aerial and earth terminals of the set.

Impact Voltages

The best value of inductance can only be found by trial, but a tuning coil with a natural wavelength of about 1,000 metres will probably be effective. The idea behind this balanced aerial is that voltage surges, impact voltages and sundry forms of interference set up a train of damped oscillations in the aerial and the inductance coil with an average frequency equivalent to the natural wavelength of the aerial.

Some of the energy is induced in the secondary circuit and reaches the set, but is at a frequency that is not used for normal broadcasting, and is easily tuned out in a selective receiver, hence some interference is eliminated. In some cases a tuning condenser or preset condenser across the primary may be beneficial

Trailing Earth

Another scheme that is well worth trying out is a "trailing earth"—that is—a short length of chain or steel wire rope attached to the metal frame of the car and long enough to trail on the ground.

On steam lorries this trailing earth wire has proved beneficial as a static discharger and has relieved the vehicle of electrical charges accumulated from various and sometimes obscure causes.

Finally it is useful to carry a length of flexible wire with a terminal tag on one end and an ordinary earth tube at the other. This is used when the car is stationary as a direct earth lead by driving the tube into the earth and attaching the wire to the earth terminal of the set; this usually results in an increase of signal strength.

Battery Elimination

In some makes of car fitted with an alternating current generator it is sometimes practicable to devise and fit a rectifier valve and a voltage doubler and use the unit in the same way as a "mains" H.T. unit. It is also feasible to use a dynamotor either as a trickle charger or to supply H.T. current through a filter and smoothing circuit, but at present it would appear to be advisable to use independent L.T. and H.T. batteries in the usual way.

SERVICING

PHILCO RECEIVERS

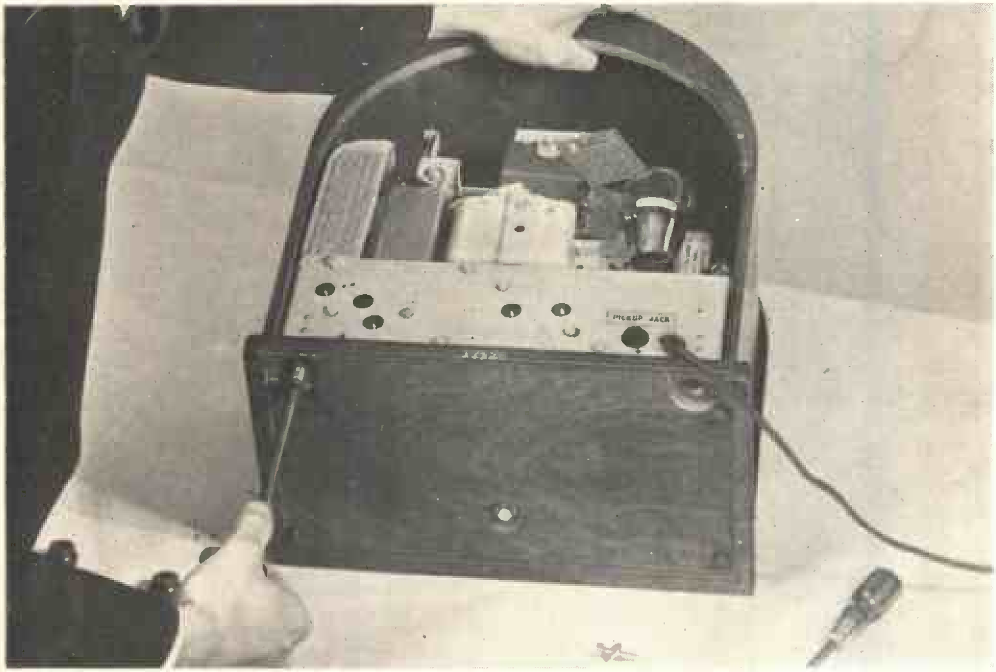


Fig. 1.—REMOVING THE CHASSIS OF THE PHILCO RECEIVER MODEL 55. FIRST OPERATION.

Take out the three Parker-Kalon screws from beneath the chassis. Note that these three screws should not be tightened hard down after replacement ; they should be left sufficiently loose to permit the chassis to float on the rubber pads between the chassis and the bottom of the cabinet.

THERE need be no hesitation to service any Philco receiver on the grounds of unfamiliarity with American-type circuits and valves.

A few minutes' study of the circuits given in the following pages will prove that in actual fact the arrangement of components to serve given purposes is just as simple, if not more simple, than the customary arrangements with which everyone is familiar.

Tables are given which indicate the working voltage measurable at various points in the circuits, so that if a very much higher or lower voltage than normal is obtained at any point, that point should be found in the circuit diagram, when straightforward reasoning will indicate where the fault may lie.

Defective Valves or Defective Resistances

The majority of faults will be found to be due either to defective valves or defective resistances. Certain receivers employ more than one valve of the same type ; in such cases these valves may be interchanged in their various sockets, and if any change in the reproduction of a given station occurs, one of these valves may be assumed to be the cause of the trouble. Substitution of valves (under the terms of the 90-day valve warranty) will thus cure most troubles, and if a reliable ohmmeter is at hand, resistances may be accurately checked.

The Weston Model 564 combined volt-ohm-meter was used to compile the test tables. This has an internal resistance of 300,000 ohms on its 300 volt range. If a meter of lower internal resistance is used, due allowance must be made for the lower readings which will be obtained.

Fig. 2.—REMOVING THE CHASSIS. SECOND OPERATION.

Remove the knobs by pulling them from their spindle, on which they are a force fit. They may be levered off by finger pressure from behind as shown.

What to do if a Low Resistance Voltmeter is used for Testing

If a meter of considerably lower resistance is used, say 6,500 ohms, the readings obtained must be checked against a calculated figure. The formula is:

$$V_m = \left(\frac{R_m}{R_m + R_x}\right)V$$

where V_m is the meter reading.

R_m is the internal resistance of meter.

R_x is the total series resistance external to the meter.

V is the voltage of the main H.T. supply.

An Example of Checking by Calculation

As an example of the necessity for checking by calculation, suppose the negative lead from the meter is connected to the cathode of the detector valve in the Model 56, and a reading of only 3 volts is obtained from the anode of the valve using a meter with an internal resistance of 6,500 ohms.

Is this correct (the Table gives 70 volts to be read here) or is there a fault present?

The first thing to do is to look carefully at the theoretical circuit diagram of the receiver, from which it will be seen that there are four resistances in this part of the circuit between the meter and the H.T. Supply, three (35, 38 and 39) in the anode circuit, and one (33) in the cathode return circuit. These total to 720,000 ohms. The measured H.T. voltage across the electrolytic condenser is 250 volts; therefore, substituting these values in the formula already given, we obtain the following, which illustrates the method of using the formula.

$$\begin{aligned} V_m &= \left(\frac{R_m}{R_m + R_x}\right)V \\ &= \left(\frac{6500}{6500 + 720000}\right)250 \\ &= \left(\frac{6500}{726500}\right)250 \\ &= \left(\frac{13}{1453}\right)250 \\ &= \frac{3250}{1453} \\ &= 2{\cdot}2 \text{ volts.} \end{aligned}$$

Thus the approximate reading of 3 volts corresponds sensibly with this calculated value of 2·2 volts. This example illustrates the necessity of a good high resistance meter for accurate work, as the actual *calculated* anode voltage on this valve is of the order of 160 volts.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SERVICING PHILCO RECEIVERS

RECEIVER DESIGN

THE TUNED ANODE THREE

WIRELESS COMPASS

1/-

Part 19

IN ABOUT 24 WEEKLY PARTS

PART 19.

REMOVING THE CHASSIS FROM THE CABINET

The procedure outlined here is for the Model 56 A.C. receiver as illustrated in Figs. 1–3. The essentials of the procedure apply equally to all other models, including radio-gramophones.

The greatest care must be taken not to touch any of the trimming condensers at the back of the chassis, and particularly the one which is exposed on the side of the rear section of the gang condenser, otherwise one or other of these may be thrown out of adjustment, thus rendering the set insensitive, or causing flat tuning.

In the case of the Model 256 Radio-Gram., and the 56 and 55 Lowboy receivers it is necessary to unsolder the four leads from the back of the speaker. See also "Excessive Mains Hum."

Fig. 3.—REMOVING THE CHASSIS. THIRD OPERATION.

Take a firm grip of the back of the gang condenser, taking the greatest care not to touch any of the trimming condensers (behind the various holes in the back of the chassis and on the side of each section of the gang condenser) and lift out. One of the soft rubber pads on which the chassis normally floats can be seen inside the bottom of the cabinet.

SLIPPING DIAL

Dial slip will seldom be encountered with the Model 56 or any of the 1932/33 receivers, but may occasionally occur with the Model 55 T.R.F. receiver.

Causes of Dial Slip

Released spring-pressure on the drive washers causes the fault and is due to the horseshoe-shaped cotter washer having slipped out of its socket in the small dial drive assembly spindle; or, excessive spring pressure on main gang condenser spindle may be causing it to bind.

The second cause of the trouble may be tested by first releasing the dial on the main condenser spindle by slacking off the grub screw as shown in Fig. 6 when the condenser vanes may be rotated independently, and any unevenness in the pressure required to do this noted. Such unevenness may be corrected by easing the pressure of either the front or the rear tensioning spring. The front one is seen clearly in Fig. 13, the rear one occupies a similar position at the other end of the spindle.

If no unevenness is noted the chassis must be taken out of the cabinet and the dial drive assembly examined.

Examining the Dial Drive Assembly

First take off the dial. The dial retaining screw has already been loosened (Fig. 6). Now rotate the dial to its full extent clockwise, and withdraw from the spindle (Fig. 7). Take out the single Parker-Kalon screw which holds the dial drive assembly on the condenser body (Fig. 8). This illustration clearly shows the cause of the trouble, the small cotter washer is seen to be falling away from behind the assembly as the latter is released.

Reassembling the Dial Drive

Fig. 9 shows the component parts of the assembly in the order in which they must be re-assembled.

Note.—The loose drive washer already

OPERATING DATA FOR PHILCO 55-A AND 55-E RECEIVERS

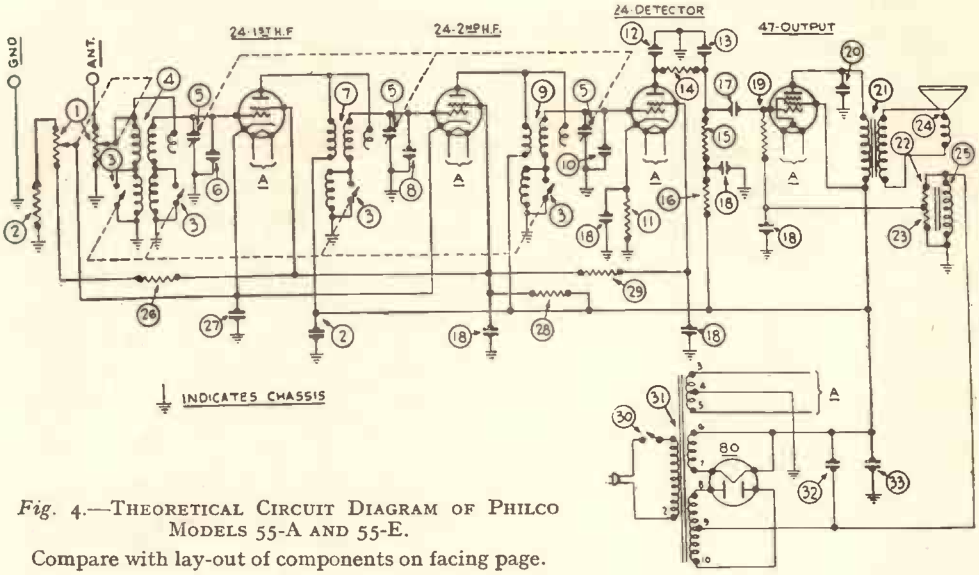


Fig. 4.—Theoretical Circuit Diagram of Philco Models 55-A and 55-E.

Compare with lay-out of components on facing page.

Table 1.—Valve Socket Readings taken with A.C. Set Tester A.C. Line—As Voltage stated on Chassis

Valve.		Filament Volts.	Plate Volts.	Screen Grid Volts.	Control Grid Volts.	Cathode Volts.	Plate Milli-amperes.
Type.	Circuit.						
24	1st H.F.	2·4	250	90	2·5	3·0	4·5
24	2nd H.F.	2·4	250	90	2·5	3·0	5·5
24	Det.	2·4	100	42	8·0	8·0	0
47	Output	2·4	175*	190*	10·0*	—	27·0
80	Rect.	5·0	—	—	—	—	20/20

Note.—Volume control on full; station selector turned to low-frequency end.

* These readings must be taken from the underside of the chassis, using test prods and leads unless the set checker is specially equipped for testing pentode valves.

Table 2.—Power Transformer Voltages.

Terminals.	A.C. Volts.		Colour.
1–2	As labelled	Primary	Black (small gauge)
3–5	2·5	Filament of 24 and 47	Black
6–7	5	Filament of 80.	Light Blue
8–10	700	Plates of 80	Yellow
4	—	Centre tap of 3–5	Black, yellow tracer
9	—	Centre tap of 8–10	Yellow, green tracer

Table 3.—Condenser Data.

No. on Figs. 4 and 5.	Capacity (Microfarads).	Container.
(12) (13)	·00025	Yellow
(17) (20)	·01	Black bakelite container
(27)	·18	Black bakelite container
(18)	·1, ·15, ·25, 2-·5 (55-A) ·05, ·15, ·25, 2-·5 (55-E)	Metal container
(2)	·05 and 150 Ohm resistor	Black bakelite container
(32)	(55-A) 10	Electrolytic.
(32) & (33)	(55-E) 6	Electrolytic

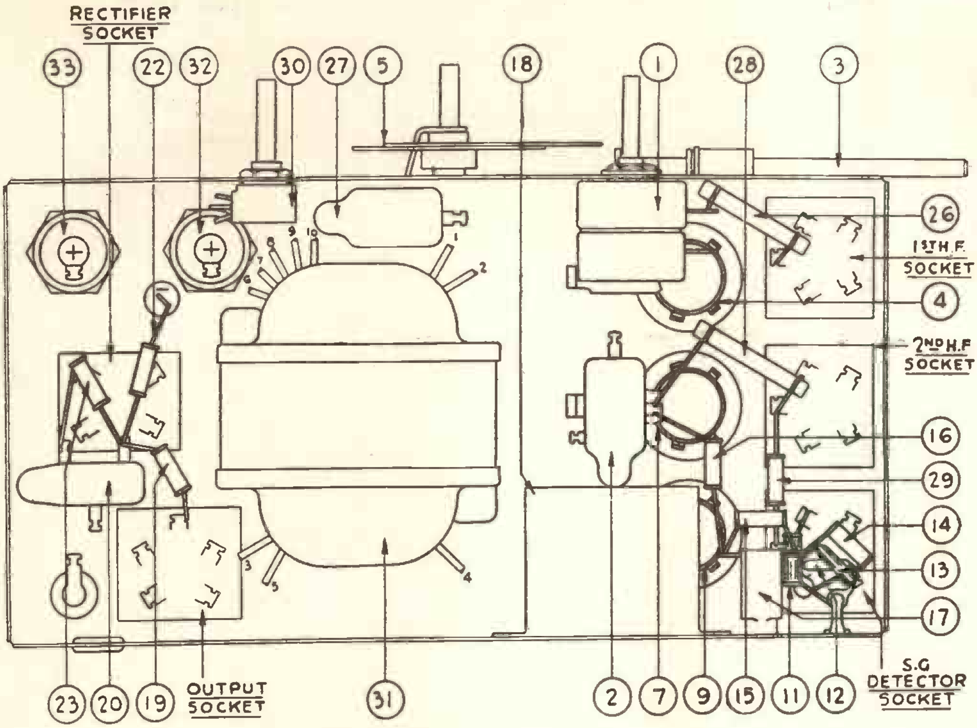


Fig. 5.—Lay-out of Components of Philco Models 55-A and 55-E.

on the spindle has curved surfaces. *The side with the raised centre* (*i.e., the convex surface*) *must face the solid brass drive washer,* which is an integral part of the small spindle, otherwise erratic operation will result after reassembly.

A convenient hole is placed in front of the gang condenser in the chassis, into which the drive spindle may be dropped, and the parts dropped in place. Place a box spanner over the end of the spindle, and insert the cotter washer under the edge. Press down to compress the spring, and squeeze the cotter into its slot with a pair of pliers as shown in Fig. 13. The assembly may now be removed, and the cotter washer pressed right home as in Fig. 14.

Table 4.—Resistor Data.

No. on Figs. 4 and 5.	Resistance (Ohms).	Power Rating (Watts)	Colour.		
			Body.	Tip.	Dot.
(2)	150 and ·05 Mfd.	—	Black Bakelite Container		
(14)	10,000	·5	Brown	Black	Orange
(26)	15,000	1·	Brown	Green	Orange
(28)	25,000	1·	Red	Green	Orange
(11)	32,000	·5	Orange	Red	Orange
(16) (29)	99,000	·5	White	White	Orange
(23)	160,000	·5	Brown	Blue	Yellow
(15)	240,000	·5	Red	Yellow	Yellow
(19) (22)	490,000	·5	Yellow	White	Yellow

Fig. 6.—Loosening the Grub Screw releases the Dial from the Main Condenser Spindle.

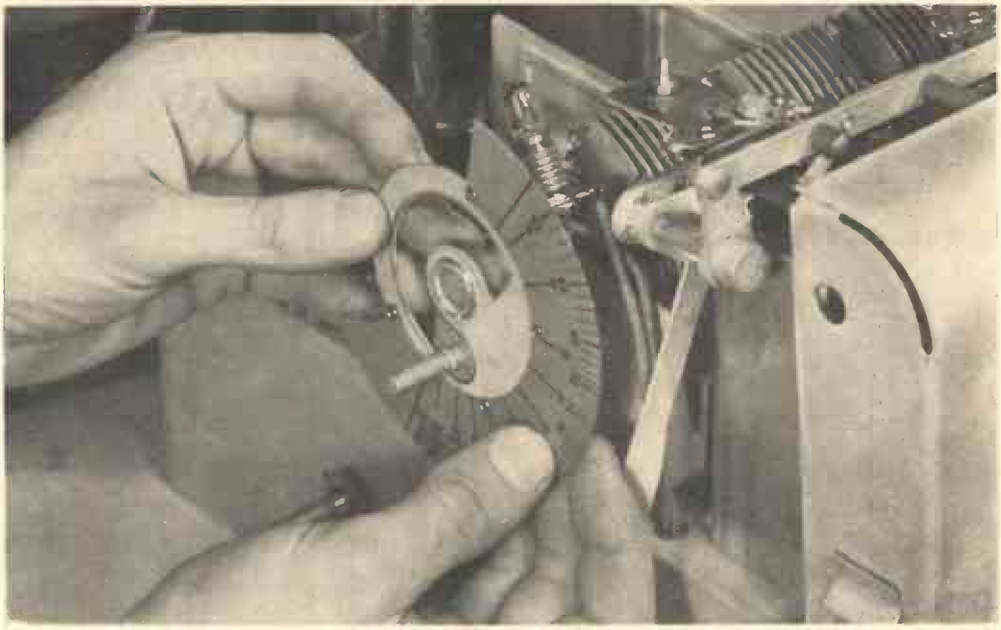


Fig. 7.—Withdrawing the Dial Drive Assembly.

Having freed the dial from the main spindle, rotate it clockwise when it may be withdrawn as shown.

Fixing the Cotter Washer

The cotter washer used on many Model 55's is of a different shape to the one illustrated, but the procedure is identical. The corners should be slightly curled up after reassembly, or a spot of solder applied to prevent a recurrence of the trouble. The form illustrated may simply be squeezed round the spindle after it has been pressed home.

Fig. 8.—Taking out the Parker-Kalon Screw which holds the Dial-Drive Assembly on the Condenser Casing.

Note the small U-shaped washer slipping out from behind the assembly ; this has slipped out of its slot in the small spindle and has released the grip of the springs, thus causing the dial to slip.

Reassembly into Chassis

Refit the drive assembly as in Fig. 8 and the dial as in Fig. 7. Now rotate the dial to its full extent anti-clockwise, and rotate the condenser vanes similarly, and tighten the grub screw as shown in Fig. 15. The dial will now be found to read correctly when tuning-in known stations, and the chassis may be replaced in the cabinet.

COMPLETE SUDDEN CESSATION OF OPERATION—ALL MODELS

(1) Observe if all valves heat up ; it is possible that a heater-wire, or a filament has open-circuited.

Note.—Many type 24 valves have the top of the cathode tube pinched-up, whilst in others it is left open. Thus the white-hot heater wire may be visible in some cases, but in others only the dull red glow of the cathode is visible.

Fig. 9.—Component Parts of the Dial-Drive Assembly in their Order for Re-assembling.

Note the relationship of the curved surfaces of the loose drive washer (on the spindle) to other parts. The convex side must face the solid brass drive washer. Note also the slot into which the cotter washer fits.

(2) Remove the protecting shield from the back of the speaker (Fig. 20) and measure the voltage across the two outer connectors, as in Fig. 16. If this has dropped much below the normal 40 to 50 volts, or has risen to about 130 volts, tests must be made for condenser breakdown under the chassis. The above test applies to A.C. Models 55 and 56 only.

Take out the chassis, connect the voltmeter negative lead to chassis (or mains neg. if D.C.) and use the 300 volt range. Measure the anode voltage of the I.F. valve (Fig. 21). This should be almost the same as the reading obtained on the electrolytic condenser (Fig. 22)—about 250 to 270 volts according to the mains input voltage, and 16 volts less than the mains input to D.C. sets.

If the reading obtained is considerably lower, disconnect the lead to the positive side of each electrolytic condenser in turn and note whether the voltage rises to approximately normal. If so, replace the defective condenser. Similarly, disconnect each of the connections to the filter condenser block in the D.C. receivers, reconnecting each one if no

OPERATING DATA FOR PHILCO MODEL 56

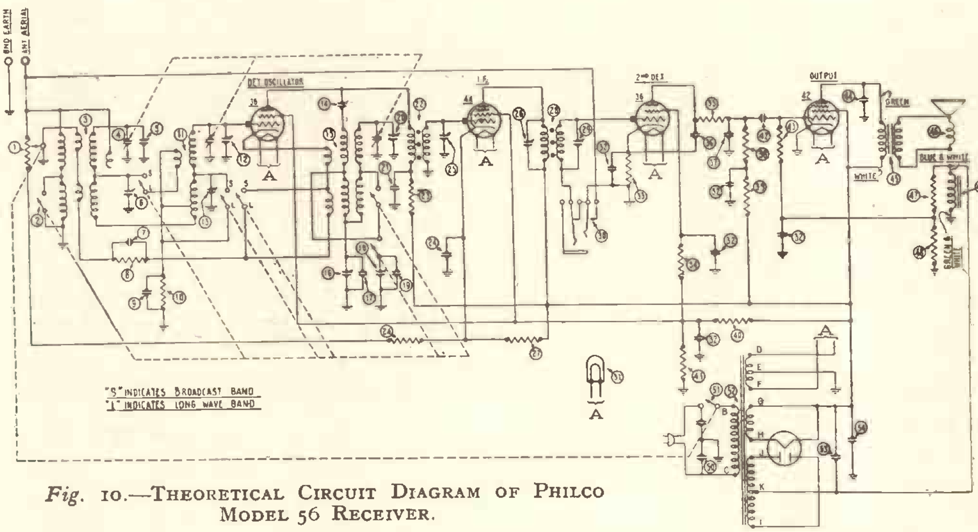


Fig. 10.—Theoretical Circuit Diagram of Philco Model 56 Receiver.

Table 1.—Valve Socket Data*—A.C. Line Voltage. 230 Volts, 50 Cycles.

Valve. Type.	Valve. Circuit.	Filament Volts F to F.	Plate Volts. P to K.	Screen Grid Volts. SG to K.	Cathode Volts. K to Chassis.	Control Grid Volts. CG to K.
36	Mod.-Osc.	6·3	250	95	+9	−8·6
44	I.F.	6·3	250	95	+4†	−4†
36	Det.	6·3	70	55	+6	−7
42	Output	6·3	240	250	0	−8
80	Rectifier	5·0	340/340	—	—	—

* All of the above readings were taken from the underside of the chassis, using test prods and leads with a suitable A.C. voltmeter for filament voltages and a high resistance (300,000 ohm) multi-range D.C. voltmeter for all other readings. Volume control at maximum, and station selector turned to low-frequency end. Readings taken with a radio set tester and plug-in adapter will NOT be satisfactory.

† Volume control at maximum. Read 32 volts when volume control rotated to minimum position.

Table 2.—Power Transformer Data.

Terminals on Fig. 10.	A.C. Volts.	Circuit.	Wire Colour.
B–C	Type A 120, " E 230	Primary	White
D–F	6·3	Filament	Black
G–H	5·0	Filament of 80	Light Blue
J–L	680	Plates of 80	Yellow
E	—	Centre Tap D-F	Black with Yellow
K	—	Centre Tap J–L	Yellow with Green

Table 3.—Resistor Data.

Nos. on Figs. 10 and 11.	Resistance (Ohms).	Power (Watts).	Colour. Body.	Colour. Tip.	Colour. Dot.
(23)	1,000	·5	Brown	Black	Red
(33)	32,000	1·0	Orange	Red	Orange
(8)	8,000	·5	Grey	Black	Red
(41)	25,000	1·0	Red	Green	Orange
(40)	32,000	1·0	Orange	Red	Orange
(27)	51,000	3·0	Green	Brown	Orange
(35)	51,000	·5	Green	Brown	Orange
(10) (34) (39)	99,000	·5	White	White	Orange
(48)	160,000	·5	Brown	Blue	Yellow
(38) (43) (47)	490,000	·5	Yellow	White	Yellow
(24)	250	·5	Combined with ·05 mfd. condenser.		

On the F type transformer, common primary wire is white; 200-volt tap is black and white; 230-volt tap is green; 260-volt tap is red.

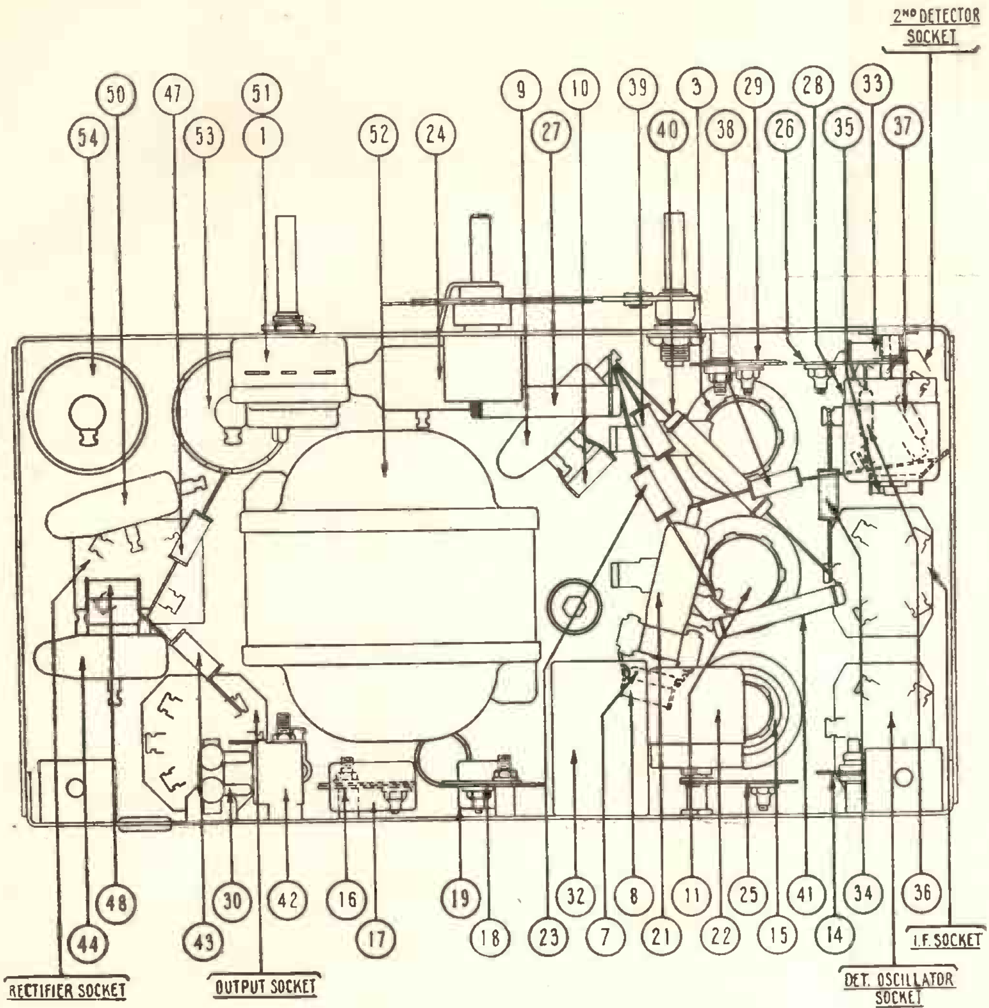


Fig. 11.—Lay-out of Components of Philco Model 56 Receiver.

change occurs, until the defective section is traced.

(3) If the grids inside the output valve are red-hot, and no signals are reproduced from speaker, test for continuity across two middle connectors on the back of the speaker after having turned the set off. The output transformer primary winding will be found burnt out—open circuited.

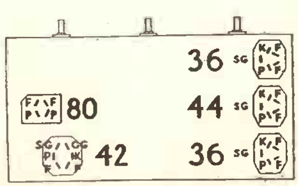


Fig. 12.—Valve Sockets, Underside of Chassis.

F, filament; SG, screen grid; K, cathode; P, plate; CG, control grid. *Caution.*—Never connect the chassis to the power supply unless the speaker is connected and all valves are in place.

Failure to Switch on

(1) Remove chassis, and carefully try short-circuiting the two switch connectors (on the back of the volume control in Models 56, 247, 248 and 71).

(Do not attempt to do this on the multi-contact on-off switch in the Model 237 battery receiver. The fault there would no doubt be due to the two-volt accumulator having run down.)

Resumption of operation will indicate that the switch is at fault. This is replaceable complete with volume control where these are a combined instrument. A separate mains switch is used in the Model 55 only.

(2) A burnt-out power transformer is at once evident from the odour, and usually results from the set being connected to a power supply whose voltage either fluctuates considerably * or is higher than that indicated on the licence label on the rear of the chassis.

Noisy Volume Control

Model 55.—Spring off the cover of this component and carefully clean the contact surface of the top (large wire-wound) resistance element with a piece of soft rag. Also clean the underside (contacting surface) of the moving contact by feeding the cloth under its edge and drawing through. Care must be taken not to bend this arm, as once bent it cannot be made to reconnect with the resistance.

The centre pick-up contact should be cleaned in the same manner, and if the spring pressure appears weak, the lower moving contact may be carefully bent upwards a little, but not so far as to cause the top contact to touch the volume control cover when this is replaced.

The lower small resistance element which is the grid-bias potential divider for the H.F. amplifying valves will never require attention.

Other Models

Poor contact between the moving arm and the resistance element cannot occur, but the control may be noisy at one point, about one-third of the way up from zero. If the volume of the station being received drops suddenly at this point, the volume control should be replaced, as a continuity

Fig. 13.—Drop the Drive Spindle with its Component Parts into the convenient Hole in the Chassis in the Position shown.

Insert the cotter under the edge of the box-spanner and press down, at the same time squeezing the cotter into its place.

Fig. 14.—Pressing the Cotter into its Slot.

After the operation shown in Fig. 13. the cotter is only half way home. Press it right into its slot as shown and close it round the spindle. Where a flat cotter is used, curl up the corners after assembly to prevent it slipping out again at any time.

* A voltage variation greater than plus or minus 5 per cent. is legal claim for compensation from the Power Supply Company. (Fine £5 on conviction and £5 per day during continuance of offence—*vide* Electricity Commissioners).

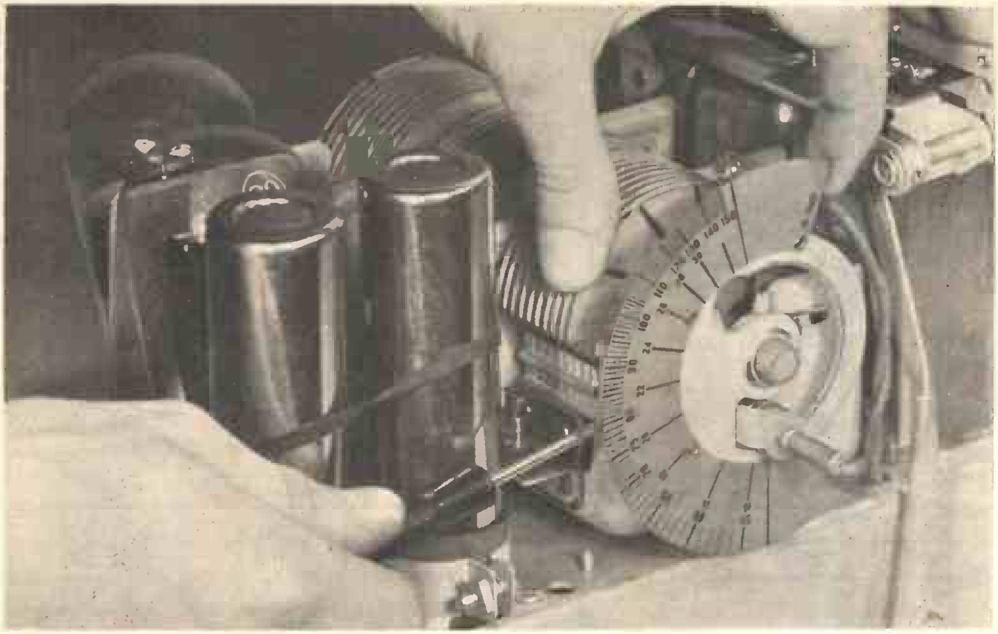


Fig. 15.—Replace the Dial on the Spindle and Rotate all the Way Anti-clockwise.
Rotate the condenser vanes similarly, and lock the dial on the spindle in this position by re-tightening the grub screw as shown.

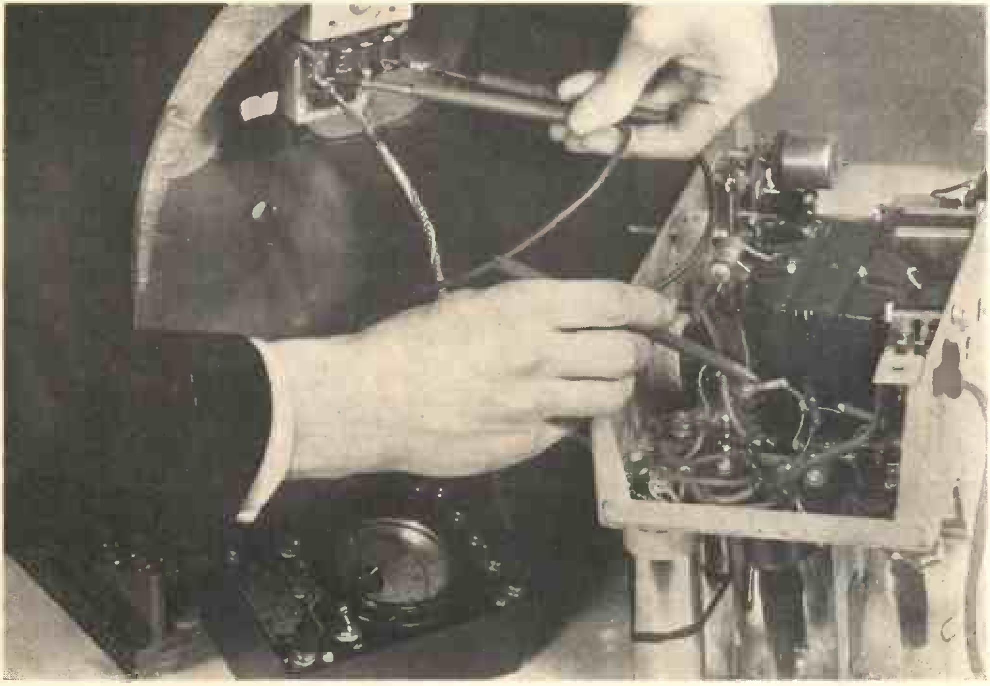


Fig. 16.—Testing across the Two Outer Speaker Connectors.
The meter shows 100 volts instead of the normal 40–50 volts. The pencil points to the cause of the trouble—a resistance broken down, due no doubt to the presence of a defective output valve.

OPERATING DATA FOR PHILCO MODEL 237

The Philco Model 237 is a five valve battery operated superheterodyne receiver designed for dual wave operation of 550 to 1,500 kilocycles (545 to 200 metres) and 150 to 300 kilocycles (2,000 to 1,000 metres).

Volume equal to that of most A.C. receivers and economy in high-tension battery consumption are highly important features of the circuit. The filaments are supplied from a 2-volt accumulator.

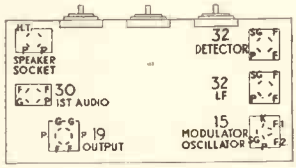


Fig. 17.—VALVE SOCKETS, UNDERSIDE OF CHASSIS. MODEL 237.

When connecting batteries to the receiver, first connect the low tension and turn the receiver switch on. Now connect the grid bias and finally the high tension.

The filament current drain from the accumulator is 720 milliamperes (·72 amp.).

The plates are supplied from high-tension batteries from 120 volts to 135 volts. At 135 volts the H.T. current drain varies between 7 and 11 milliamperes according to the output volume.

The intermediate frequency of the superheterodyne circuit in this model is 125 kilocycles.

TABLE 1.—VALVE SOCKET DATA.

Valve.		Filament Volts F to F.	Plate Volts P to F.	Screen Grid Volts SG to F.	Control Grid Volts CG to F.	Cathode Volts K to F.	
Type.	Circuit.					F_1	F_2
15	Modulator Osc.	2·0	120	70	−4·5 (cath.)	−3·5	−2·0
32	I.F.	2·0	120	70	−3 to −8	—	—
32	Detector	2·0	50*	50	−4·5	—	—
30	1st audio	2·0	110	—	−0·4	—	—
19	Output	2·0	120/120	—	−3·0	—	—

* Measured with 300,000 ohm meter; if measured with 30,000 ohm meter read 8 volts.

TABLE 2.—RESISTOR DATA.

Nos. on Figs. 18 and 19.	Resistance (Ohms)	Colour.		
		Body.	Tip.	Dot.
(25) (41)	1,000	Brown	Black	Red
(1)	2,900	Red	White	Red
(17)	5,000	Green	Black	Red
(31)	25,000	Red	Green	Orange
(30)	51,000	Green	Brown	Orange
(34) (35) (37)	99,000	White	White	Orange
(33a)	240,000	Red	Yellow	Yellow
(40)	490,000	Yellow	White	Yellow
(9)	1,000,000	Brown	Black	Green

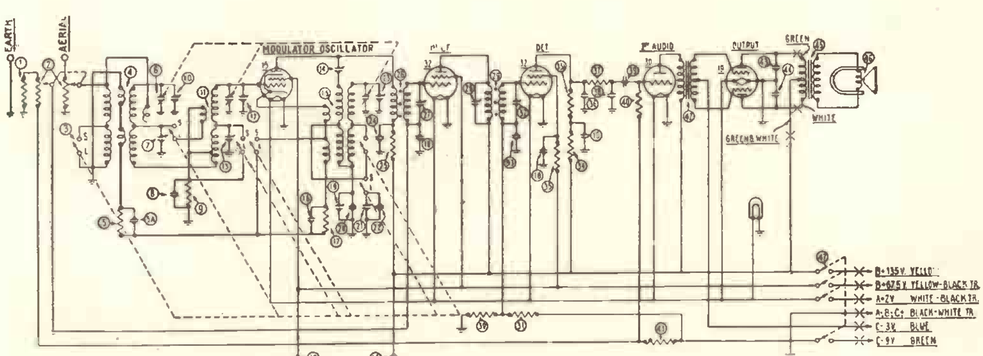


Fig. 18.—THEORETICAL CIRCUIT DIAGRAM OF PHILCO MODEL 237 RECEIVER.

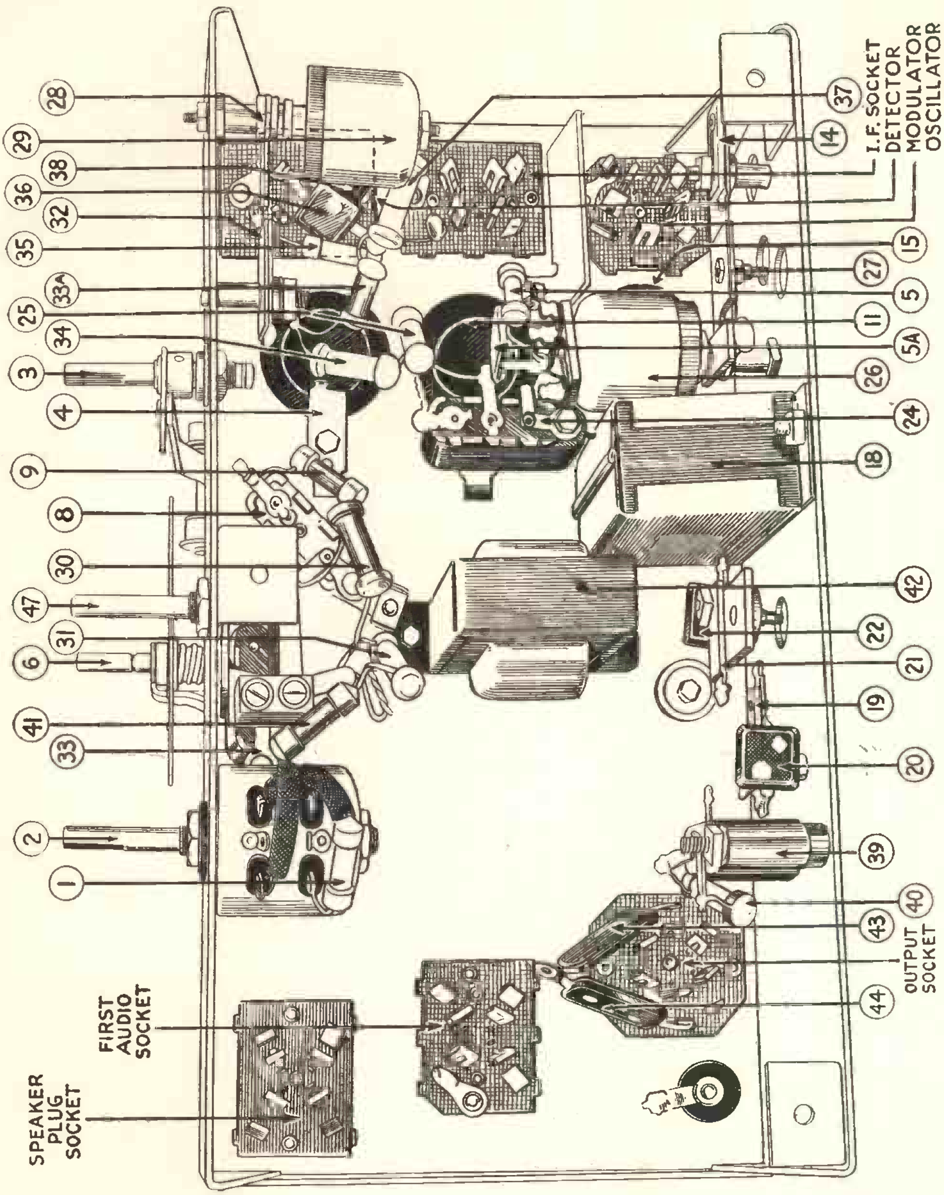


Fig. 19.—Layout of Components of Philco Model 237 Receiver.

test across the two outer connections (after the leads have been disconnected) will show an open circuit.

Model 237 Volume Control

The Model 237 (battery receiver) volume control is in two sections; the above continuity test should be made on the rear section.

SUDDEN VARIATION IN VOLUME AND/OR TONE OF REPRODUCTION. ALL MODELS.

Turn on the receiver, and smartly tap each of the screen-grid valves. A rattle will be reproduced through the speaker in the case of a defective valve sympathetic with the vibration of the bulb, or a simultaneous variation of volume of the station being received will occur.

If the above test proves fruitless, and the reproduction suddenly becomes thin and high pitched periodically, the fault will be found in the coupling condenser between the detector valve and the succeeding stage, being due to periodic open-circuiting of the connections inside the condenser moulding.

The connection of a condenser of any value between ·01 and 2 mfd. across the terminals of the suspected condenser will cause resumption of normal operation and thus indicate the suspected internal open-circuit to be true, when the part may be replaced.

If either of the above faults are evident all voltages should be checked in conjunction with the appropriate table, as erratic functioning of a resistance will cause the same defect.

GRADUAL FADING OF REPRODUCTION WITH OR WITHOUT DISTORTION. A.C. OR D.C. RECEIVERS.

(1) A defective valve may cause this trouble through an internal leak developing across the mica bridge or glass support bead inside the bulb, due to the presence of a minute film of the flashed metal in the lower half of the bulb (the "Getter") changing to low resistance under the influence of the heat generated within the valve. Test as already described for erratic operation.

(2) Note whether all the elements within the type 47 or 42 output pentode valve remain sensibly cool. If the grids are red hot, measure the voltage developed across the speaker field coil as in Fig. 16. If this approximates to 100 volts, one of the two potential dividing resistances in the output valve grid biassing circuit has open-circuited, leaving this valve with no grid bias. The defective resistance is being indicated in the photograph.

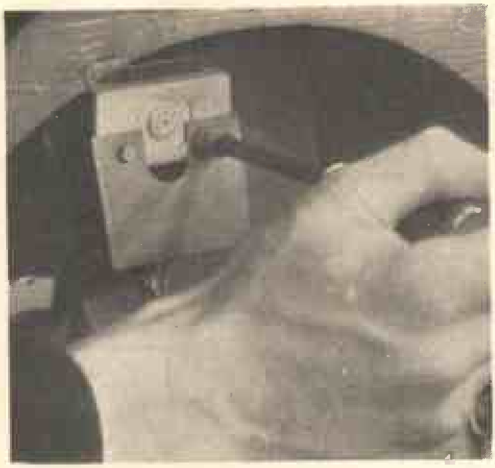


Fig. 20.—This shows the Two Parker-Kalon Screws on the Loud Speaker.

These only hold the protective cover in place. Measurement of the voltage across the two outer connectors behind the cover is the best indication of the presence of any serious fault in the set. Note that this does not apply to D.C. receivers where the voltage across the field is 16 volts.

Shunting this resistance with a $\frac{1}{4}$ megohm resistor whilst reading the speaker field voltage will return the reading approximately to normal. If it does not, the output valve should be replaced by a new one.

Note.—The voltage read across the speaker field may be translated directly as milliamperes, and indicates the total H.T. current consumption of all valves. Thus the normal reading of 50 volts indicates that 50 milliamperes are flowing. The field coil is in the *negative* H.T. lead in all A.C. sets, therefore, if it is desired at any time to connect an extension speaker to the set, the field coil connections must be left undisturbed, otherwise the grid bias to the output valve will be upset.

HOW TO CURE SPEAKER RATTLE

First, take out the centering screw from the centre pole-piece. Next unsolder the two voice-coil leads from the two connectors on the flare of the speaker, making a note of which lead was disconnected from which connector. Now take out the six Parker-Kalon screws round the periphery of the diaphragm, and lift the cone away. If it will not come away easily, carefully insert a thin-bladed knife between the fibrous cone rim and the metal flare, and ease up all round.

The gap should now be cleared of any metal filings by means of a cycle pump or other source of air pressure, and the speaker then reassembled. Carefully centre the voice coil in the field gap, and lock in position with the centering screw. This should be the last operation of reassembly. Care should be taken to replace each voice coil lead on the connector from which it was originally removed.

EXCESSIVE MAINS HUM. A.C. AND D.C. RECEIVERS

"Persuasion filters" rather than "Brute-force filters" are used in all Philco sets. Thus neutralisation effects part of the smoothing-out of residual hum which gets past the filters.

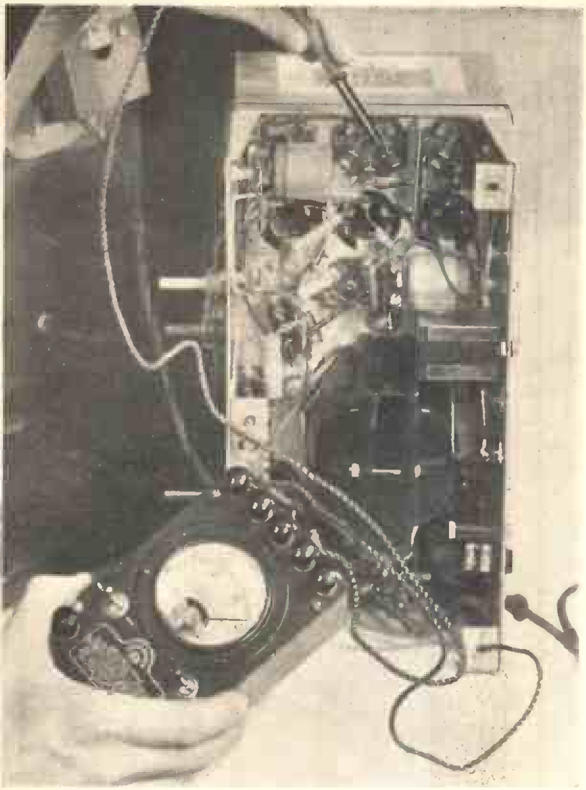


Fig. 21.—TESTING THE VOLTAGE AT THE ANODE OF THE SECOND SCREEN-GRID VALVE POINT.

This gives the same reading as in Fig. 22. The meter negative lead is connected to the chassis. Failure to obtain a reading here indicates a burnt out I.F. transformer.

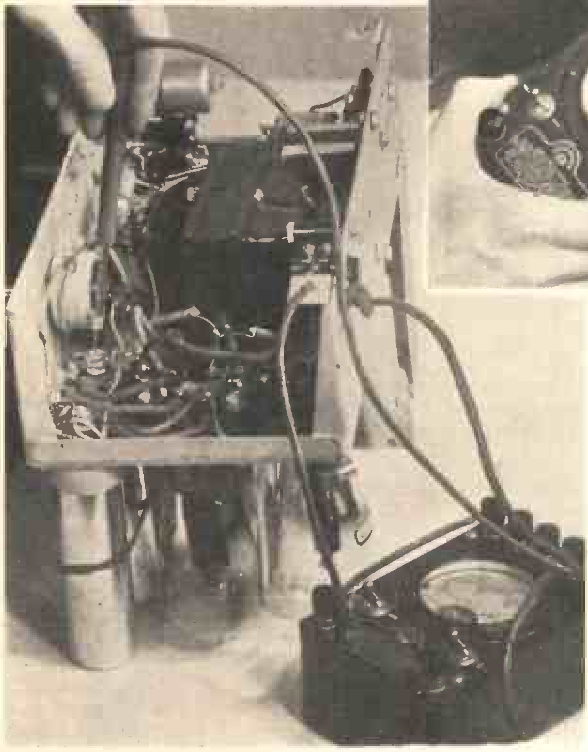


Fig. 22.—TESTING THE ELECTROLYTIC CONDENSERS.

The meter reads 270 volts between the chassis and the positive side of the electrolytic condensers. These condensers are, therefore, O.K. If the voltage here was down, the positive side of each of these condensers should be disconnected in turn to find which one is the cause of the fault.

Note.—The voltage between the cans (negative) of these condensers is the same as that across the speaker field coil. Thus field voltages may be measured there equally well.

Residual hum is present in the anode circuit of the output valve. Residual hum is also present in the field coil. Thus if these two hum voltages are fed together *out of phase* with each other they will neutralise and effectively disappear.

If the four connections on the back of the speaker are made in the wrong order, these hum voltages will *add together, and be reproduced*.

OPERATING DATA FOR PHILCO 248-E RECEIVER

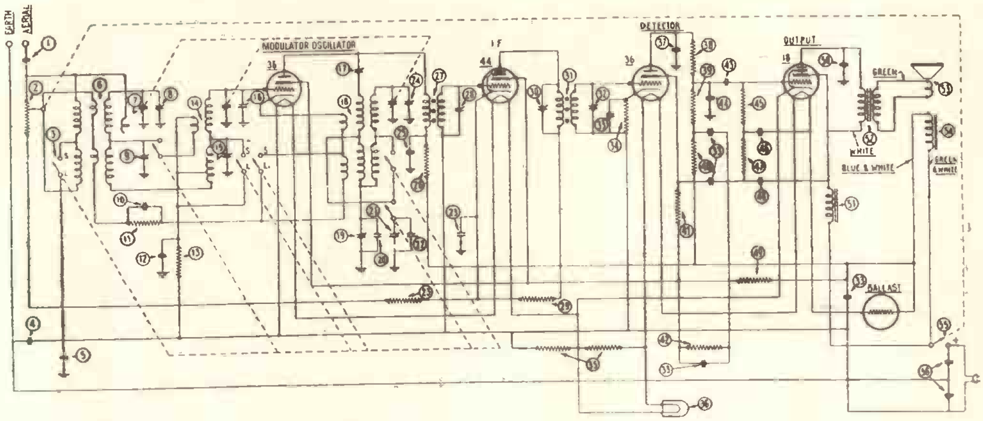


Fig. 23.—THEORETICAL CIRCUIT DIAGRAM OF PHILCO MODEL 248-E RECEIVER.

TABLE 1.—VALVE SOCKET DATA*.

Valve Type.	Circuit.	Filament Volts F1 to F2.	Plate Volts P to K.	Screen Grid Volts SG to K.	Control Grid Volts CG to K.	Cathode Volts.	
						K to F1	K to F2.
36	Modulator Osc.	6·3	196	87	—6	+ 1	+ 7
44	I.F.	6·3	190	83	— 3†	— 8	— 2
36	Detector	6·3	80	63	—10	—14	— 8
18	Output	14·0	190	200	— 5	— 5	—24
7	Ballast	170·0	—	—	—	—	—

* Line volts 220. All readings taken with 300,000 ohm D.C. voltmeter.
† With volume control at maximum. When in minimum position read —10.

TABLE 2.—RESISTOR DATA.

Nos. on Figs. 23 and 24.	Resistance (Ohms).	Power (Watts).	Colour.		
			Body.	Tip.	Dot.
(35)	50 & 300	—	Wire	Wound	
(23)	250	—	Combined with ·05 mfd. Condenser		
(26)	1,000	·5	Brown	Black	Red
(11)	8,000	·5	Grey	Black	Red
(49)	25,000	1·	Red	Green	Orange
(42)	32,000	1·	Orange	Red	Orange
(34) (38)	51,000	·5	Green	Brown	Orange
(29)	51,000	2·	Green	Brown	Orange
(13) (40) (41) (47)	99,000	·5	White	White	Orange
(39)	240,000	·5	Red	Yellow	Yellow
(45)	490,000	·5	Yellow	White	Yellow

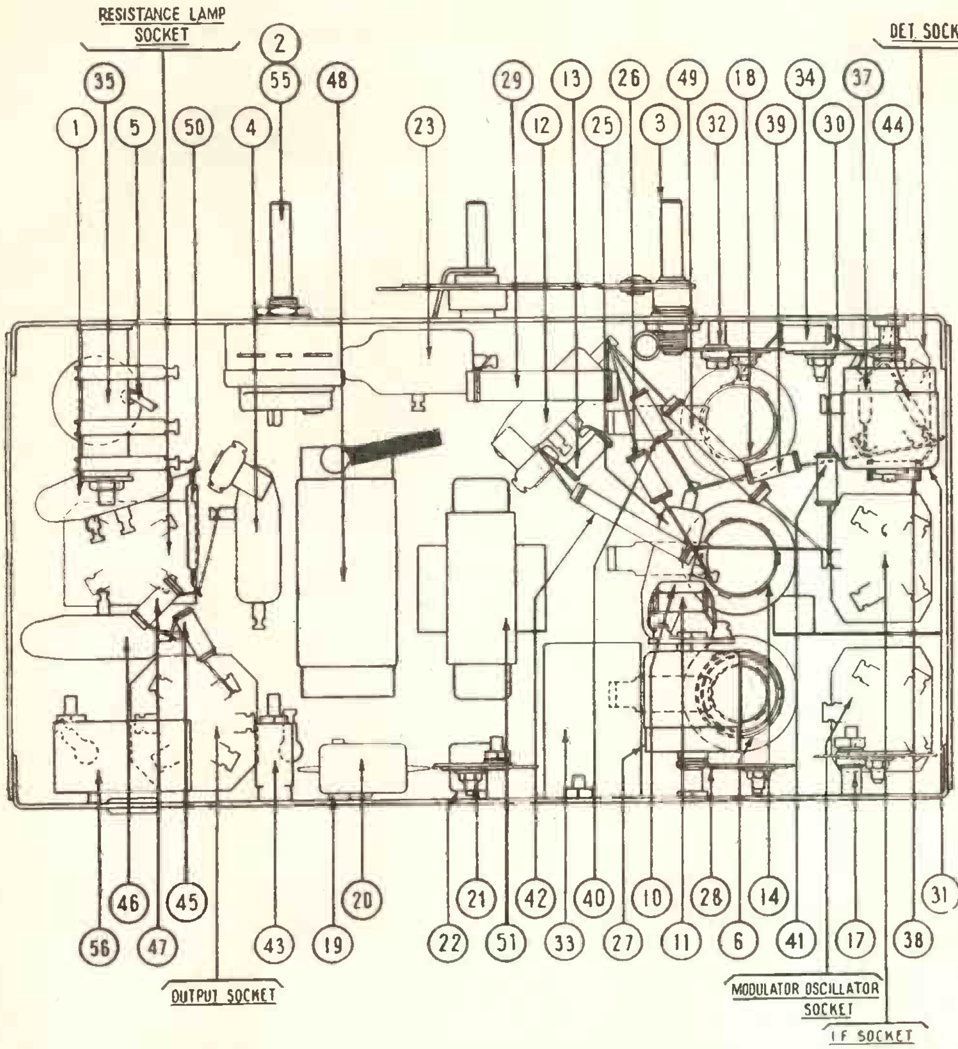


Fig. 24.—Lay-out of Components of Philco Model 248-E Receiver.

To correct this, it is only necessary to disconnect *the two outer connections* (*field*) and reconnect them reversed.

Modulation Hum

Hum, which is evident only when a station is tuned-in, is called "Modulation hum," and is due to the use of an inefficient earth connection to the receiver, *i.e.*, an earth which runs in the opposite direction to the aerial, or goes to earth a long way from the active earth immediately between the aerial. Attention to the aerial and earth will cure this.

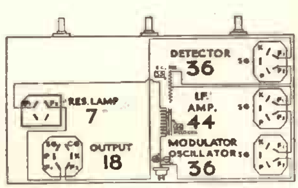


Fig. 25.—Valve Sockets, showing Valve Heater Circuit.

Never withdraw any valve whilst the receiver is switched on.

FAULTS PECULIAR TO CERTAIN RECEIVERS

71XL Radiogramophone

In rare instances it may be found that this receiver has a tendency to shrillness or even actually to squeal

OPERATING DATA FOR PHILCO 247-E RECEIVER

TABLE 1.—VALVE SOCKET DATA*—D.C. LINE VOLTAGE 230 VOLTS.

Valve. Type.	Valve. Circuit.	Filament Volts F1 to F2.	Plate Volts P to K.	Screen Grid Volts SG to K.	Control Grid Volts CG to K.	Cathode Volts. K to F1.	Cathode Volts. K to F2.
36	Modulator Osc.	6·3	205	80	—10	—30	—36·3
44	First I.F.	6·3	210	90	— ·2	—28·5	—35
44	Second I.F.	6·3	205	90	— 9	—23	—29·5
37	Diode Det.	6·3	—	—	—	—16	—22·3
37	First Audio	6·3	95	—	— 5	+2·3	— 3·8
37	Second Audio	6·3	195	—	—10	+16	+ 9·7
18 / 18	Push-pull Outfit	15·3	215	218	—14·8	—58 / —43	—43 / —28
8	Ballast (res.) lamp	162	—	—	—	—	—

* All above readings taken on underside of chassis, using test prods and leads with a D.C. meter of 300,000 ohms resistance. Readings taken with a radio set-tester and plug-in adapter, will not be satisfactory.

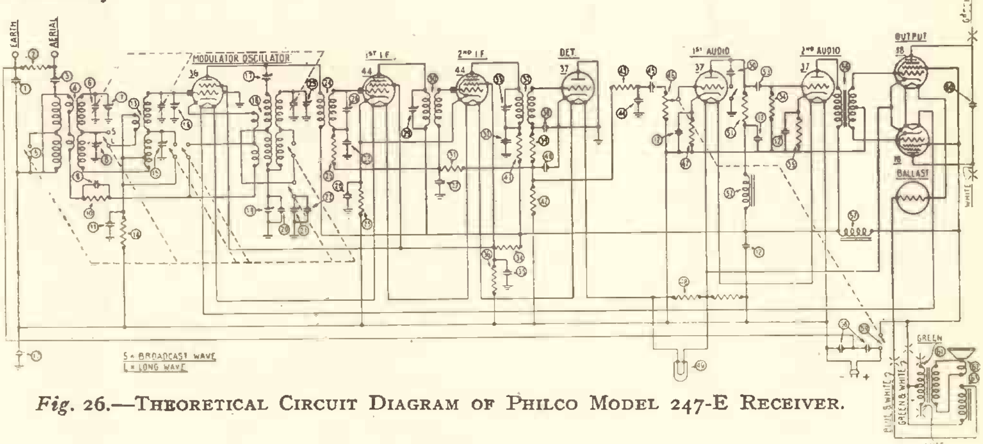


Fig. 26.—THEORETICAL CIRCUIT DIAGRAM OF PHILCO MODEL 247-E RECEIVER.

TABLE 2.—RESISTOR DATA

Nos. on Figs. 26 and 27.	Resistance (Ohms).	Colour. Body.	Colour. Tip.	Colour. Dot.
(48)	50 & 300	Tubular	Wirewound	
(41)	1,000	Brown	Black	Red
(2) (55)	5,000	Green	Black	Red
(10) (47)	10,000	Brown	Black	Orange
(34)	25,000	Red	Green	Orange
(36)	32,000	Orange	Red	Orange
(25)	51,000	Green	Brown	Orange
(14) (39) (43) (51)	99,000	White	White	Orange
(42)	240,000	Red	Yellow	Yellow
(54)	1,000,000	Brown	Black	Green
(31)	2,000,000	Red	Black	Green

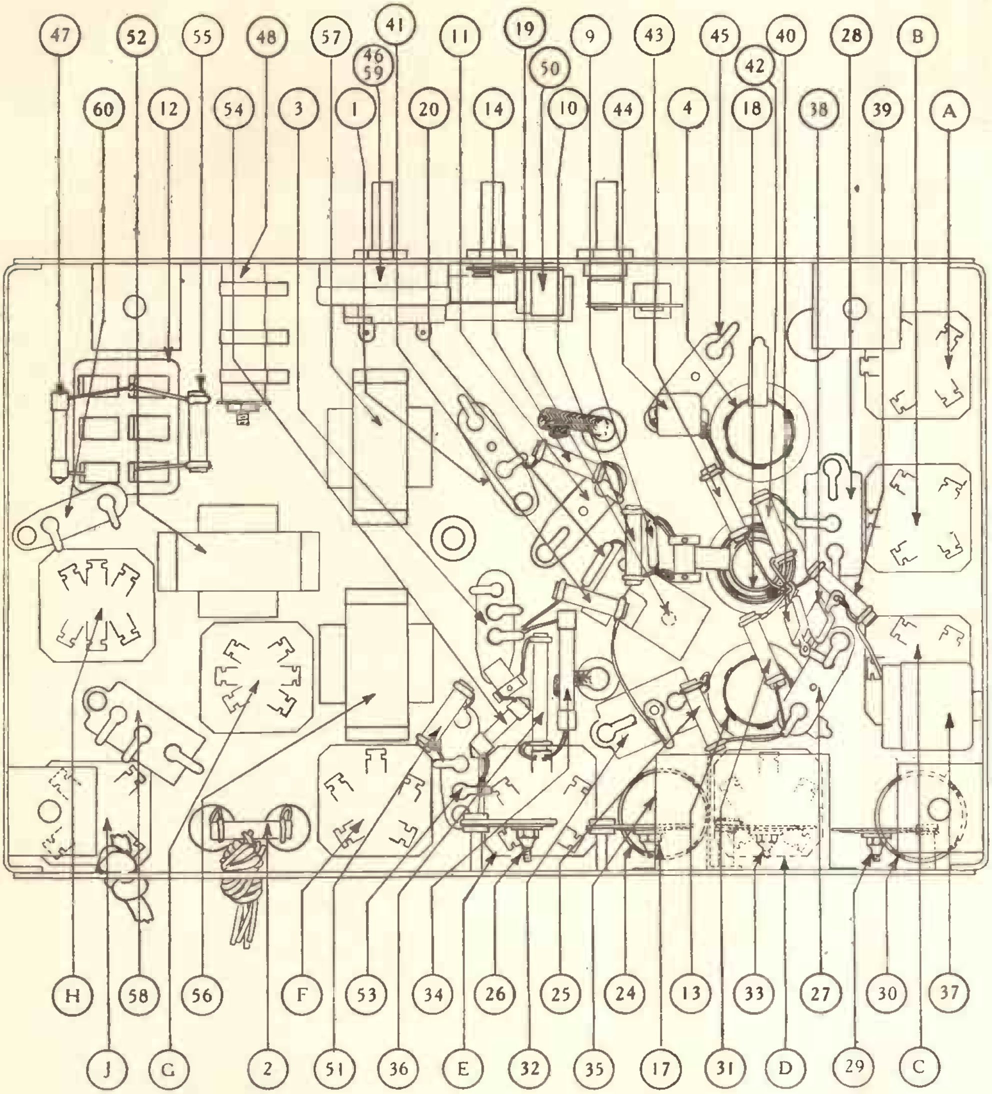


Fig. 27.—LAY-OUT OF COMPONENTS OF PHILCO MODEL 247-E RECEIVER.

on radio when the tone control switch is set in the "brilliant" position. This is due to stray coupling between the control-grid and anode circuits of the pentode audio-frequency amplifier and pentode output valve.

A yellow lead crosses the chassis from beneath the bunch of four leads from the radio/gramo change-over switch, to the volume control.

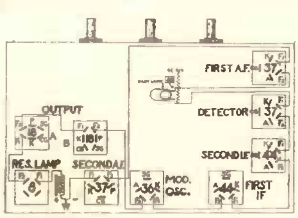


Fig. 28.—VALVE SOCKETS SHOWING ORDER OF CONNECTION OF SERIES VALVE HEATER CIRCUIT.

Never withdraw any valve whilst the receiver is switched on.

A rubber-covered lead traverses the chassis in a similar direction between the speaker output socket and the tone control. If these leads have dropped close to one another in transit this squeal will be produced.

The rubber-covered lead should be dressed as far away from the yellow lead as possible, when the trouble will be cured.

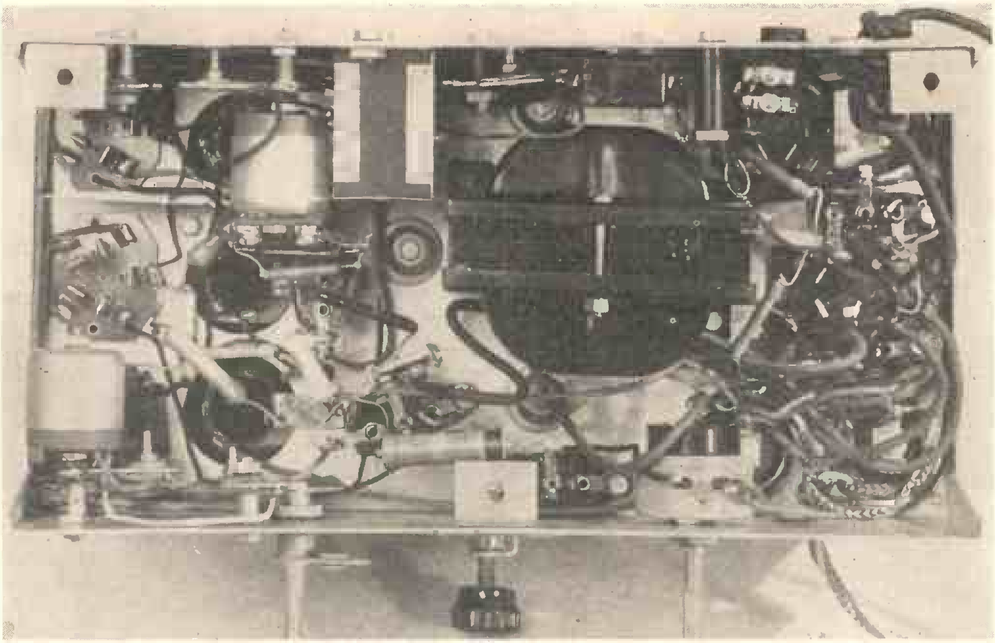


Fig. 29.—PLAN VIEW OF THE UNDERSIDE OF THE PHILCO MODEL 56 SUPERHETERODYNE.

Although both I.F. transformers look alike they are electrically different, and must not even be interchanged with those used in similar positions in other receivers.

Similarly, the twisted pair of leads from the volume control should be redressed at the point where they pass the tone control if the first process does not cure.

Model 237 Battery Receiver

It will be found that sudden failure to operate below certain dial settings is generally caused by the modulator oscillator valve ceasing to oscillate, due to insufficient high-tension voltage. If the H.T. battery has dropped below 100 volts *on load*, *i.e.*, with the set operating, the grid bias positive wander plug may be moved up one hole, *i.e.*, $1\frac{1}{2}$ volts, thus giving the amplifier valve $7\frac{1}{2}$ volts bias in place of 9 with a corresponding reduction of grid bias to the R.F. amplifying valves. The output valve will then be biassed to $-1\frac{1}{2}$ volts instead of -3 volts.

WARNING.—This change of grid bias must not be made until the H.T. battery has dropped to 100 volts, also the receiver *must be switched off* before any grid-bias connections are changed, otherwise the valves will be seriously damaged.

Note.—If the H.T. battery is replaced, the grid bias should also be replaced.

The voltage of the grid-bias battery should be measured periodically *as current is drawn from it while the set is operating*. Thus if this battery is running down, it can cause excessive H.T. battery drain and reduce the life of both the H.T. battery *and the valves*.

Audio-Frequency Howl—Model 237 (also all other models)

This is caused through failure to slack off the three bolts on the underside of the cabinet to permit the chassis to float on the soft rubber pads placed there for this purpose. The cabinet must necessarily vibrate to some extent sympathetically with the output from the speaker, and the chassis must float on the rubber pads in order that cabinet vibration is not transmitted to the chassis, and so to the valves.

The tuning condenser, it will be seen, is similarly mounted on rubbers in order that this vibration will not reach the condenser vanes to cause a similar effect through "frequency modulation." These condenser mounting bolts must on no account be touched, otherwise the receiver will be thrown out of balance and rendered insensitive.

If the chassis is floating correctly, and the trouble persists (it can only do so with the battery set) the fault lies with the type 32 valve nearest the front of the cabinet. Try the effect of interchanging this valve with the similar valve in the middle socket of these three. Continued persistence of the trouble calls for replacement with a non-microphonic type 32 valve.

Oscillation on the Low-Frequency (Long Wave Band) in the Model 55

This in many cases is caused by allowing the aerial to cross the back of the set close to the tuning condenser. The remedy is obvious.

Alternatively, it may be caused by the amplification of stray H.F. currents by the output valve. This may be cured by (*a*) carefully dressing the long control-grid lead down against the chassis, or, (*b*) disconnecting this lead from the pentode valve holder, and inserting a 100,000 ohm resistance in series. This resistor functions as a high-frequency choke, and effectively prevents stray H.F. impulses reaching the valve grid, and yet offers sensibly no impedance to the audio-frequency component from the previous valve which it is desired to amplify.

OUTPUT CIRCUIT OF PHILCO BATTERY RECEIVER

As the Model 237 battery receiver employs an output circuit which differs considerably in its essential principle of operation from accepted practice, a brief description will not be out of place here.

Reference to the circuit diagram of this receiver will indicate that the type 19 output valve consists of two 3-electrode valves in the one bulb. Each of these valves has actually two grids which are bonded together inside the valve to form one grid of very fine mesh.

Differences from Usual Practice

It will also be noted that the circuit itself appears to be a conventional push-pull arrangement. Whilst this is so in principle it is different in actual fact. The type 30 valve which follows the type 32 detector valve performs the function of what is known as the Driver Stage ; the transformer in its anode circuit is not a conventional step-up transformer, but a step-down transformer whose secondary winding has a very low D.C. resistance.

Only a Small Negative Bias required

As previously stated the grids of the two valves enclosed in the one bulb of the type 19 output valve are of very fine mesh and, therefore, only a small negative grid bias is required to bias each half of the valve to the bottom bend of the grid volts/anode current characteristic. The diagram shows that the centre tap of the transformer feeding these two grids, connects to —3 volts grid bias, this voltage being sufficient almost to stop anode current flowing.

The signal fed through the transformer from the driver valve to each of the type 19 valve grids is of the order of 17 volts when reproducing at full volume. Thus it follows that as the grid bias is only —3, the grids will become considerably positive on the positive half of each input grid swing ; again it follows that in consequence of this, considerable grid current must flow through the two halves of the secondary of the input transformer. If an ordinary transformer were used here, magnetisation of the core would result and distortion inevitably follow, but as was previously mentioned this transformer has very low D.C. resistance in its secondary windings and, therefore, this reverse grid current has a negligible effect on quality of reproduction.

Harmonic distortion (even harmonic) appears at the anode of each valve, due to the fact that two valves are in use " back to back." This cancels out in the output transformer and consequently is not reproduced in the speaker.

Advantages of Push-push Amplification

This type of output circuit is known as " Class B " or push-push amplification, each half of the output valve *operating only on the positive half of each input grid swing*. The advantages of " Class B " amplification over " Class A " amplification (*i.e.*, the conventional method of biassing the valve to the middle point of the

OPERATING DATA FOR PHILCO 271 SERIES RECEIVERS

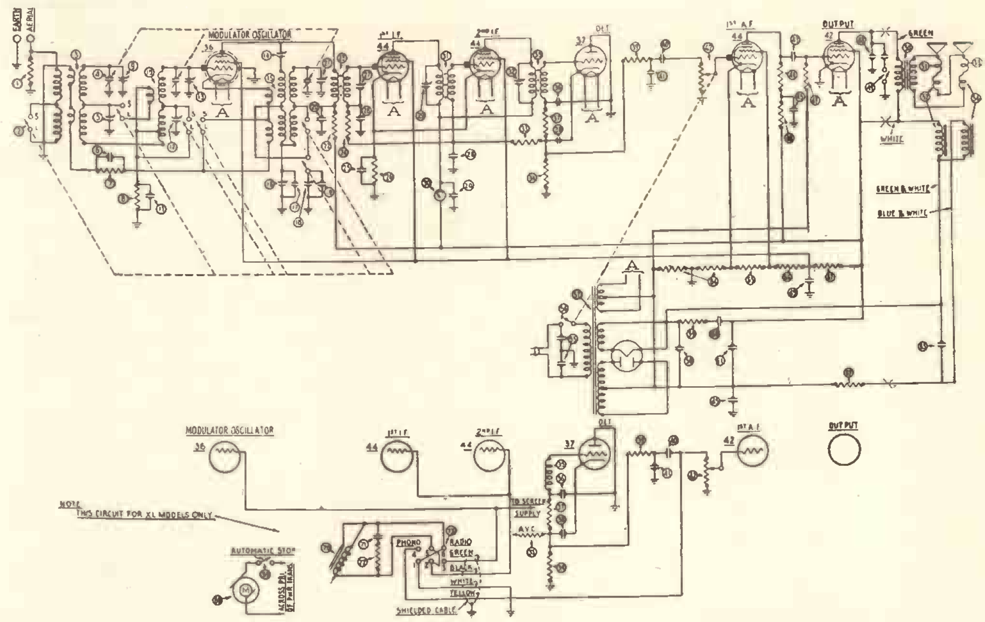


Fig. 30.—Theoretical Circuit Diagram of Philco Model 271 Series Receivers.

Table I.—Valve Socket Data*—Power Line Voltage 230.

Valve. Type.	Valve. Circuit.	Filament Volts F to F.	Plate Volts P to K.	Screen Grid Volts SG to K.	Control Grid Volts CG to K.	Cathode Volts K to F.
36	Det. Osc.	6·3	245	80	9·0	20
44	First I.F.	6·3	240	75	1·0	6
44	Second I.F.	6·3	240	75	1·0	20
37	Second Det.	6·3	0	—	1·1	15
44	First Audio	6·3	40	45	1·0	20
42	Output	6·3	230	250	2·2	15
80	Rectifier	5·0	330/330	—	—	—

* All of the above readings were taken from the underside of the chassis, using test prods and leads with a suitable A.C. voltmeter for filament voltages and a high resistance multi-range D.C. voltmeter for all readings. Volume control at maximum and station selector turned to low-frequency end. Readings taken with a radio set tester and plug-in adapter will not be satisfactory.

Power Consumption of Various Types.

Model.	Volts.	Cycles.	Watts.
71 AX	105–125	25–40	85
71 EX	205–230	50–60	80
71 AXL	105–125	25	110
71 EXL	205–230	50	110

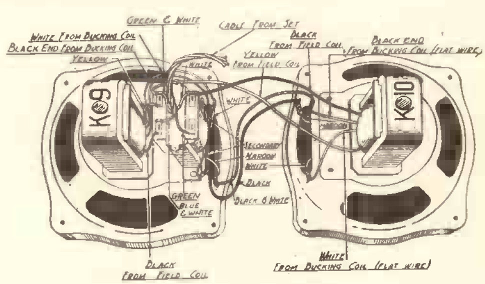


Fig. 31 (*Right*).—Twin Speaker Connections.

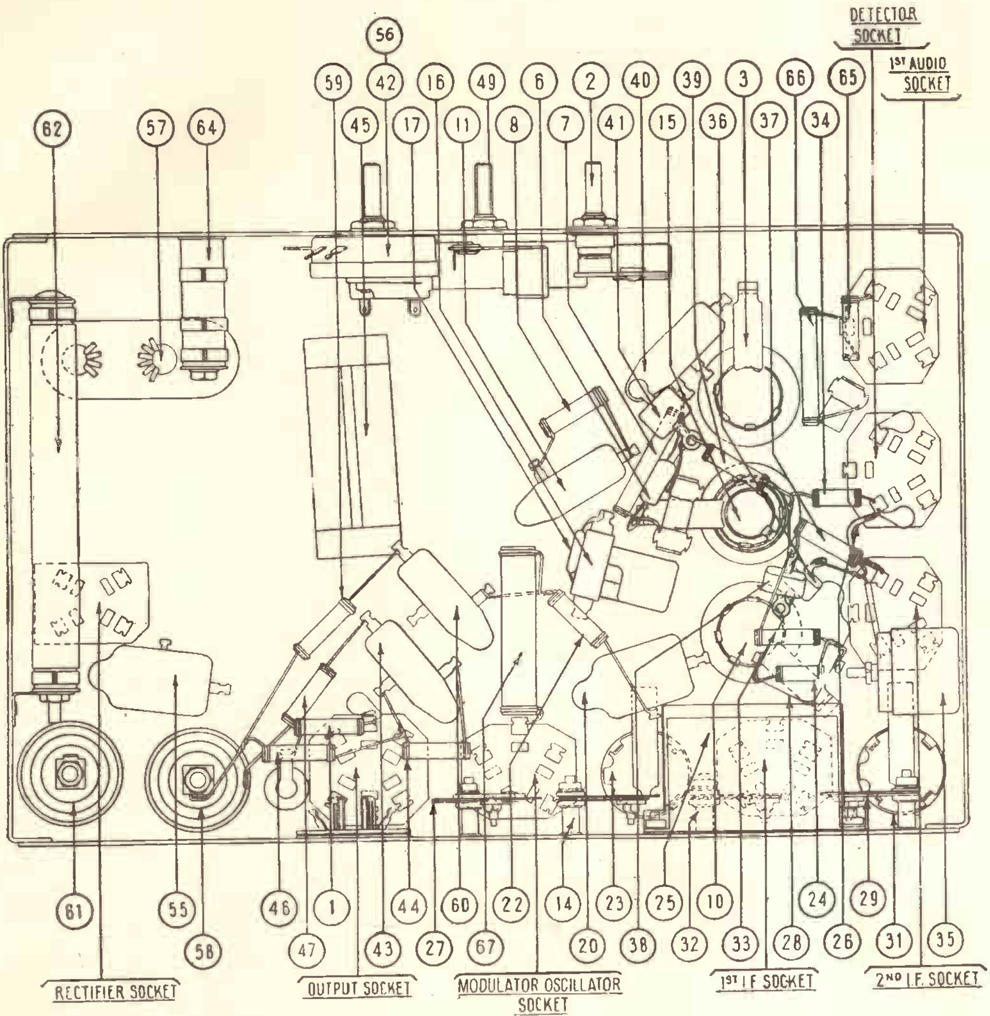


Fig. 32.—Lay-out of Components of Philco Model 271 Series Receivers.

Table 2.—Power Transformer Data.

Terminals.	A.C. Volts.	Circuit.	Colour.
1–2	205 to 230	Primary	White
3–5	6·3	Filament	Black
6–7	5·0	Filament of 80	Light blue
8–10	685	Plates of 80	Yellow
4	—	Centre Tap of 3–5	Black Yellow Tracer
9	—	Centre Tap of 8–10	Yellow Green Tracer

Table 3.—Resistor Data.

Nos. on Figs. 30 and 32.	Resistance (Ohms).	Power (Watts).	Colour.		
			Body.	Tip.	Dot.
(64)	185 & 245		Wire	Wound	
(26)	200		Flexible	Wire	
(22)	2,000	·5	Brown	Black	Red
(1) (65)	5,000	·5	Green	Black	Red
(66)	5,000	1·	Green	Black	Red
(62)	5,620		Wire	Wound	
(59) (72)	10,000	·5	Brown	Black	Orange
(7)	13,000	1·	Brown	Orange	Orange
(67)	13,000	·5	Brown	Orange	Orange
(46)	25,000	·5	Red	Green	Orange
(24)	51,000	·5	Green	Brown	Orange
(44)	70,000	·5	Violet	Black	Orange
(8) (37) (39)	99,000	·5	White	White	Orange
(34)	240,000	·5	Red	Yellow	Yellow
(48)	490,000	·5	Yellow	White	Yellow
(33)	2,000,000	·5	Red	Black	Green

straight portion of the grid volts/anode current characteristic to the left of zero grid volts), is that the entire straight portion of this curve between the bottom *and the top* bends is used instead of only the comparatively short portion to the left of zero grid volts. Thus it follows that the power handling capacity of such a valve is very considerably greater than a valve used in the conventional "Class A" circuit; the type 19 valve is actually capable of delivering 1·9 watts undistorted output to the speaker for a mean anode current consumption of approximately only 12 milliamps.

In the Model 237 receiver this power output is not made available in the interests of economic H.T. current consumption, as the *power delivered to the input transformer* by the type 30 valve is the chief determining factor in this direction, and if a larger valve were used as a driver the steady current consumption would be too high to be really economical.

An Important Point

If a milliammeter is connected in the anode circuit of the type 19 valve and no signal is being reproduced from the speaker, its steady H.T. current consumption should not exceed 4 milliamps. This value will increase progressively as the volume reproduced from the speaker is increased,—the greater the volume the greater the H.T. current consumption; therefore the fact that the needle of the milliammeter kicks about when a signal is being reproduced must NOT be taken as an indication that distortion is taking place in this valve.

This conventional test may, however, be applied in the anode circuit of the type 30 valve where distortion will occur long before the output valve is overloaded.

Do not confuse the grid bias to the types 30 and 19 valves with conventional arrangements; the type 30 requires approximately −9 volts grid bias, whilst the output valve (type 19) requires only −3.

REBALANCING

If a receiver is found to be insensitive, or the selectivity poor, and no fault can be found in the receiver circuit or valves, the various tuned circuits in the receiver must be out of resonance with one another and require "rebalancing."

Nine Tuned Circuits

There are nine tuned circuits in operation simultaneously in the models 71 and 247 on each waveband, and eight in the five valve receivers, in each case, eleven trimmers to be adjusted.

The Model 55 tuned radio-frequency receiver employs only three tuned circuits and is easily rebalanced, but on no account must any attempt be made to rebalance any superheterodyne receiver unless the necessary local tone-modulated oscillator giving signals of 125, 175, 260 and 700 kilocycles is available, together with a detailed instruction of procedure.

Rebalancing the Model 55

An insulating key will be required which will fit the small brass adjusting nuts on the trimming condensers. This may easily be made from a narrow strip of ebonite in which a slot has been cut at one end, ¼ inch wide. This key is necessary in order to eliminate hand capacity effects which would make accurate adjustment impossible.

Tune-in a weak station at the lower end of the medium waveband, *i.e.*, at about 1,300 or 1,400 kilocycles (130 or 140 dial reading).

Adjusting the Trimming Condenser

Now adjust the trimming condenser located on the side of the rear section of the gang condenser, for maximum volume. The main tuning control should not be touched during this adjustment, and not until the remaining two trimmers located on the middle and the forward sections of the gang condenser have been similarly adjusted. Now the main tuning control should be carefully readjusted, noting whether an increase in volume occurs on the station to which it was tuned, or a decrease.

If the volume decreases, make no further adjustment, but if a slight increase is observed, again tune the station accurately, and repeat the adjustment of the three trimmers, retuning and retrimming until satisfied that no further gain can be obtained.

THE WIRELESS COMPASS

By EDWARD W. HOBBS, A.I.N.A.

THE directional properties of a frame aerial are well known, and for many years have formed the basis of the wireless compass or direction finder.

Directional wireless as applied to marine navigation has greatly developed and improved during the past few years and to-day is a compulsory device that must be used on ships of over 5,000 tons, and is, in fact, fitted to craft of all sizes, including ship's life boats.

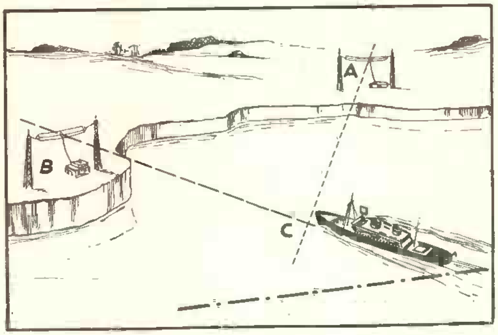


Fig. 1.—THE BASIS OF THE WIRELESS COMPASS.

The directional properties of a frame aerial are used to ascertain the bearings of two transmitting stations; the intersection of these bearings enables the captain to mark on a chart the exact position of his ship.

Basic Principles

Landsmen may be able to grasp the fundamentals of navigational direction finding by a glance at Fig. 1, where a ship is depicted as heading towards the shore, instead of maintaining its original safe course indicated by the dot and dash line.

Coastal fog or mist entirely blots out all vision, hence it is impossible for the ship's captain to see the land.

If, however, a wireless receiver with a frame aerial is on board, it can be tuned in to a transmitting station such as that indicated at A, and either the "bearing" or the angle between the station and the centre line of the ship can be determined. Then if the frame is rotated it will pick up a signal from another transmitting station, say, that at B; and another bearing taken. Thus it is comparatively simple when the intersecting point of the two bearings is known—as at C—to locate on a chart the exact position of the ship and to make any necessary corrections to the course. In actual practice there are numerous precautions to be taken to ensure the utmost reliability and efficiency. The enormous value of directional wireless in safeguarding life at sea is easily appreciated, but in addition there are many other advantages.

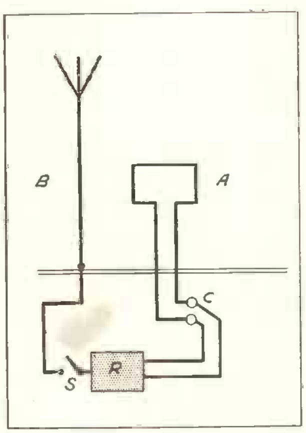


Fig. 2.—SCHEMATIC ARRANGEMENT OF DIRECTION FINDER.

The directional loop aerial is shown at A, the "sense" aerial at B; control unit at C; the receiver and amplifier at R; and sense switch at S; their functions are described in the text.

Principles of Operation

There are several makers of radio direction finders, but the following remarks apply particularly to the productions of the Radio Communication Company Limited, of London, by whose courtesy some data and illustrations are here reproduced.

The R.C.C. direction finder consists of a frame or loop aerial which can be rotated about a vertical axis, associated with a super-sensitive receiver.

Signals are heard in headphones, and are at a maximum when the plane of the loop aerial coincides with the direction of the transmitting station.

Rotation of the aerial through 360 degrees gives two zero and two maximum signals; the maxima are not sharply defined, but on approaching a zero position the signal drops to inaudibility with a "silent arc" of about 3 to 4 degrees. By observing on a scale of degrees the limits of the silent arc, the midway point between them gives the required bearing line in relation to the centre line or head of the ship.

Fig. 3.—Direction Finder on Navigating Bridge.
This shows a Radio Communication Company's radio direction finder.

Fig. 4.—In the Chart Room.
Here can be seen the extension of the frame aerial column, the control unit, and the amplifier and charging board of the Radio Communication Company's radio direction finder.

Sense Indication

Such an arrangement indicates only the line of bearing because two similar results are obtained at an 180 degrees separation; hence it becomes necessary to differentiate between them to determine the required direction or "sense" of the bearing.

Sense indication is obtained by superimposing the same signal received by a short non-directional aerial, upon that picked up by the frame aerial.

The phase relationship of the two signals is now such that during one complete rotation of the frame aerial there is one minimum and one maximum, these occurring at right angles to the two zeros obtained with the frame aerial alone.

D.F. Equipment

A complete direction-finding equipment consists of the rotating loop system, comprising the frame aerial A (Fig. 2), with supporting pedestal, indicating scale, pointer and handwheel C (Fig. 2), with automatic compensated quadrantal error connector; the receiving set R; sense aerial B (Fig. 2), and sense switch S, which is incorporated in the receiver. The accessory equipment includes headphones, L.T. and H.T. batteries, aerial isolation switch, indicating lamps, bell and push, also a charging board for re-charging the batteries from the ship's mains, together with necessary switches, instruments and controls.

Disposition of Apparatus

The rotating loop or frame aerial in the

R.C.C. system consists of a single winding enclosed in a 2-inch diameter copper tube, forming a frame 28 inches square with rounded corners, which is mounted on a brass column and can be rotated on ball bearings in an external pedestal mounted on the navigating bridge—as shown in Fig. 3—or other convenient position. The whole structure is watertight, is non-magnetic and can be put in the vicinity of the standard compass without risk of interaction. Below the deck in a suitable cabin, as shown in Fig. 4, is an extension of the loop column, which projects downwards to within comfortable reach of the operator.

Control Unit

The control unit is attached to this column and comprises a control handwheel A (Fig. 6), with which to rotate the frame aerial, a rotating scale B (Fig. 6), 10-inch diameter, marked in degrees, each being spaced rather over $\frac{1}{12}$ inch apart to ensure ease of reading and great accuracy.

Connections to the frame aerial winding are effected by means of two slip rings C (Fig. 6), and two pairs of rotating brushes arranged to prevent noises reaching the receiver.

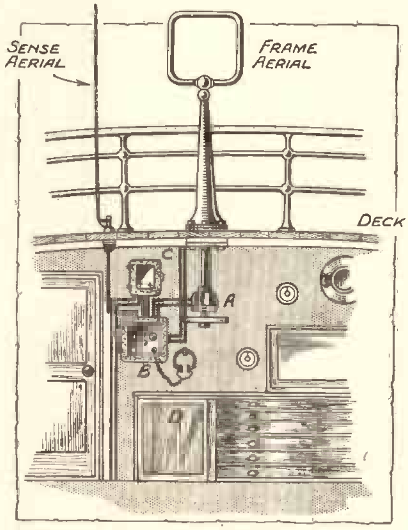


Fig. 5.—DIRECTION-FINDING EQUIPMENT.

This sectional view shows the complete equipment of a ship fitted with the R.C.C. direction finder. The control unit is at A; receiver B; charging board C; and chart table D.

Quadrantal Error

One of the most important improvements in direction finders is the incorporation of automatic correction of quadrantal error and pointer error.

Quadrantal error arises because the arrival of a wireless wave causes high-frequency currents to be induced in the metal structure of the ship, and these currents necessarily give rise to a high-frequency magnetic field.

These induced errors are quadrantal, that is to say, they reach a maximum value every 90 degrees. The amount of this error depends on the nature of the ship's structure and the position of the direction finder coil.

If the ship were electrically symmetrical the induced currents in the ship structure would produce a magnetic field in the thwartship line and the quadrantal error would be zero in directions of 0, 90, 180, 270 degrees from the bow or head of the ship.

Usually the induced field is misaligned and the quadrantal error is zero at four other angles from the bow, although they are always at 90 degrees separation.

Correcting D.F. Errors

In order to correct the direction finder it is necessary to provide adjustments to correct the errors due to magnitude and alignment of the ship's induced field, also to compensate for any slight misalignment between the pointer and the frame aerial.

Automatic correction of quadrantal error is accomplished by means of a gear wheel D in Fig. 6, mounted on a base plate on the rotating column and geared by an intermediate pinion to a toothed rim of twice the diameter on the fixed lower extension of the pedestal.

The rotating gear wheel drives the scale plate by means of an eccentric pin working in a radial slot in the scale plate and thus advances or retards the scale by the correct amount in successive quadrants.

The whole of this device is enclosed in a dust-proof cover, and once adjusted does not call for further attention by the operator, who merely reads the correct bearing direct from the scale.

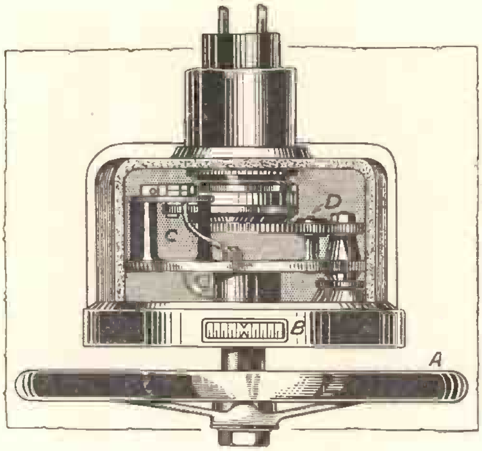


Fig. 6.—CONTROL UNIT.

The hand wheel A rotates the frame aerial, readings are taken at the scale B, the connections from frame aerial are taken through slip rings and revolving brushes C, while quadrantal errors are compensated by the gears D, as described in the text.

The Receiver and Amplifier

The receiver and amplifier consists of a very efficiently screened 5-valve super-heterodyne circuit, with the addition of the " sense " switch unit.

Valves of 2-volt low consumption type are employed in the sequence of a detector—oscillator, two S.G. intermediate frequency amplifiers, second detector with reaction, and one L.F. amplifier.

The intermediate frequency is about 75 kc.s. and the circuit arrangements are such that interaction between the oscillatory circuits and the frame aerial are negligible.

Controls comprise one knob tuning, which simultaneously tunes the frame aerial and heterodyne oscillator, the setting being indicated on a scale calibrated in wavelengths. Great selectivity is obtained by the use of three tuned I.F. circuits, all of low decrement.

Reaction Control

A rheostat in the filament circuit of the second detector valve is used to control the reaction and serves to decrease the decrement of the preceding I.F. circuit giving increased sensitivity for spark, interrupted continuous waves, or telephone reception. Further adjustment, by causing the valve to oscillate, permits heterodyne continuous wave reception.

Sense Switch

The sense switch when depressed connects the sense aerial to the receiver circuit, but when pressure on the switch is released it returns to the " off " position and thus obviates any chance of taking a bearing with the switch in the wrong position.

Isolating Switch

An isolating switch is fitted in the wireless cabin for disconnecting the ship's main aerial while the bearings are being taken, to avoid any errors due to mutual interference.

In the " off " position this switch causes indicating lamps to light in the wireless cabin and near to the directional frame. A bell near the compass is rung from a push button near the direction finder at the moment that a compass bearing is required.

Installation

The installation of a direction finder which is entirely separate from the other wireless equipment of the ship, is carried out by the makers and correctly adjusted. A typical Radio Communication Company installation is shown in diagrammatic form in Fig. 5, and shows at the top the directional loop and the " sense " aerial lead-in.

In the cabin beneath are the control unit A, receiver-amplifier B, charging board C, and the chart table D; the batteries are not shown, as they can be stowed on deck in a weatherproof casing or in any convenient position.

Operation

To take a bearing, the isolating switch is placed in the " D.F." position, thus disconnecting the main aerial and lighting the indicating lamps.

The charging board switches are set to read " receiver," showing that the batteries are connected to the set.

The receiver switch is set to " on," thus illuminating the wavelength indicator, the set is then roughly tuned by this indicator and accurately on hearing the signal.

The sense switch is then held over to the left and the frame aerial rotated by means of the handwheel until a rough minimum signal strength is obtained.

The sense switch is then released, and the frame aerial turned through 90 degrees in the direction of the arrow thereon.

The signal drops sharply to zero at about this point, the limits of the "silent arc" are noted and the midway point read on the scale, this being the actual bearing from the ship's head corrected for quadrantal error. The bell is then rung and a compass reading in degrees is taken simultaneously.

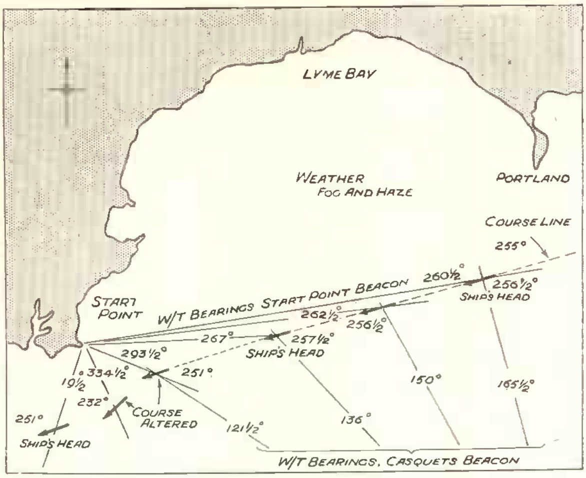


Fig. 7.—DIRECTION-FINDING CHART.

A portion of an actual chart showing wireless telegraph bearings and how the ship's course was altered to clear Start Point.

Checking Results

Results should be checked whenever possible and successive bearings taken, as indicated in Fig. 7, which is part of an actual chart showing wireless bearings taken on a coasting vessel fitted with a Siemen's wireless direction finder and reproduced by the courtesy of Messrs. Siemens Brothers, Limited, of Woolwich.

Navigators will appreciate that the compass bearing, after the usual corrections, is added to the wireless bearing and the result is the great circle bearing of the transmitting station.

If the sum of the compass and wireless bearings exceeds 360, then 360 degrees is deducted to obtain the great circle bearing. Furthermore, the "conversion angle" must be applied before plotting on a Mercator chart, if the transmitting station is seventy miles or more distant, particularly in high latitudes; this is because the wireless waves follow a great circle track.

The Rhumb line bearing for plotting on the chart is ascertained from a diagram constructed from the formula.

Conversion angle = $\frac{1}{2}$ difference longitude X sine mid latitude. The angle thus found is added or subtracted as the case may be, and gives the Rhumb line bearing.

Wide Range of Reception

Reception with the R.C.C. equipment may be carried out on spark: I. C.W., C.W., or telephony transmissions within the wave range limits of 550 to 1,100 metres, which includes the marine waveband of 600–800 metres, the aircraft wave of 900 metres and the radio-beacon wave of 1,000 metres up to distances of 100 to 150 miles, or more under favourable conditions.

If the ship is also equipped for the reception of submarine signals synchronised with the wireless transmission, a single observation will determine the direction and distance of a beacon station transmitting this type of signal.

Wireless Telephony for Shipping

The G.P.O. now have eleven coastal wireless telephony stations in operation, situated at Wick in the North of Scotland; on the East coast at Cullercoats, the Humber, and North Foreland.

Then comes Niton in the Isle of Wight, and the Land's End station. On the West coast are Fishguard, Seaforth and Port Patrick; Malin Head in Northern Ireland and Valencia in the Irish Free State.

The service area of each station overlaps that of those adjoining, thus forming a complete service area around the British Isles.

WIRELESS AUTO ALARM

By EDWARD W. HOBBS, A.I.N.A.

THE Auto Alarm is a special wireless device designed to respond automatically to the S.O.S., that is, the radio telegraph distress signal. Officially approved devices conforming to Board of Trade rules and G.P.O. requirements enable all ships of the mercantile marine, fitted with wireless, to keep a continuous watch for a possible distress signal without the necessity of an operator or watcher continually on duty. The inestimable value of such a device as an aid to the safety of life at sea, or in the air, cannot be overestimated.

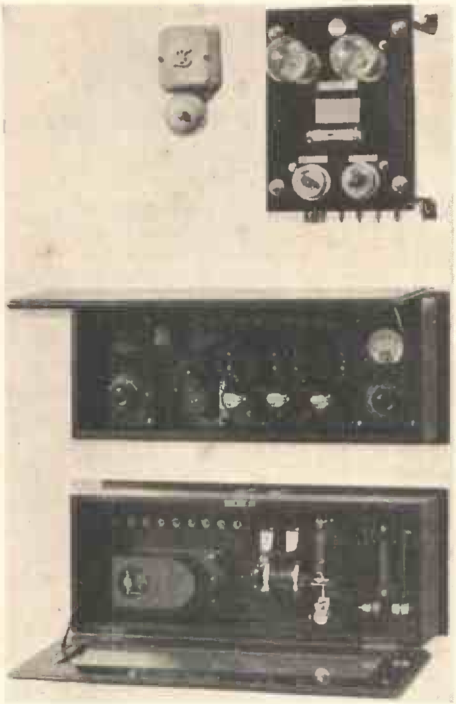


Fig. 1.—The Auto Alarm Receiver made by the Radio Communication Company.

Alarm Signal

The officially approved alarm signal consists of a series of dashes of four seconds duration, interspersed with spaces of one second each, sent for one minute. Expressed graphically against a time scale the alarm signal appears as shown in Fig. 5, and an appreciation of it will help to make clear, later, the astonishing ingenuity of the mechanism which picks out this signal only from amongst a mass of Morse, telephony and atmospherics. Having picked up the signal—three dashes are sufficient—the device automatically sounds the alarm bells and calls the ship's officers attention to the help of the distressed vessel.

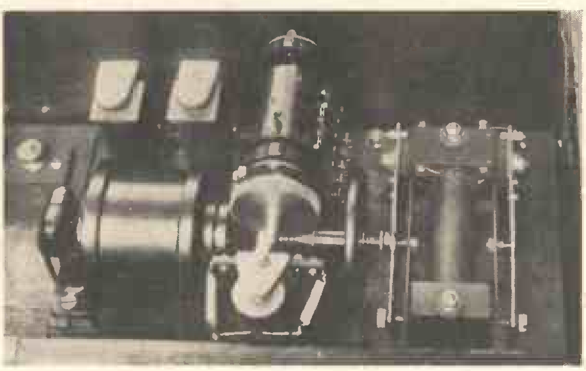


Fig. 2.—Close-up View of the Selector Mechanism of the Radio Communication Company's Auto Alarm.

The Auto Receiver

The apparatus made by the Radio Communication Company, of London, and unreservedly approved for use on British vessels is shown in Fig. 1 and consists of the auto-alarm receiver, which is quite distinct from the normal wireless receiver, and is pre-tuned to respond to any wavelength between 585 and 615 metres (the

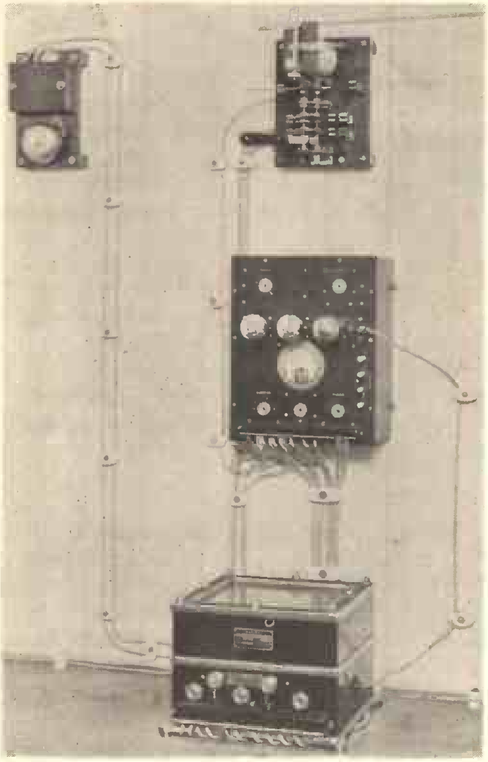


Fig. 3.—The Marconi Auto Alarm Apparatus.

agreed normal marine wavelength is 600 metres).

Three valves are used in the sequence of a detector and two L.F. transformer coupled stages. The low frequency signal is rectified in the last stage to give direct current pulses for operating the relay input of the selector.

Anode current from the last valve is adjusted by a grid potentiometer and read by a milliammeter for the purpose of biassing the input relay of the selector. The valve filaments are in series with a relay, so that if a valve should fail a special alarm is sounded continuously until the fault has been remedied.

The Selector

The selector mechanism is shown in Fig. 2 and is fitted in a closed case. It comprises a sensitive polarised relay operated by the output from the amplifier.

The selector comprises two relays, a magnetic clutch and a series of timing contacts operated by a contact cam.

A synchronous attraction type of electric motor running at 120 r.p.m. with a single non-rotating winding, drives the contact cam through the intermediary of the magnetic clutch and a 50 to 1 speed reduction gearing when a signal is received.

The speed of the motor is controlled by an electrically maintained type of tuning fork. Should the motor stop for any reason an alarm is sounded automatically.

The clutch and spacing relays are placed alongside the motor; the clutch magnet is seen next to the worm wheel in Fig. 2. The purpose of these relays is to respond when current pulses due to a distress signal are received.

Discriminating Action

The discriminating action of the selector depends on a measurement of the time of duration of all signals received; in other words, the distress alarm bell is only sounded when a signal possessing definite time characteristics is received.

Extended trials have shown that a 95 per cent. efficiency is obtained if three consecutive dashes of the alarm signal are received.

Automatic Contacts

Normally the motor runs free, but when any signal is received the clutch relay

Fig. 4.—Selector Mechanism of Marconi Auto Alarm Apparatus.

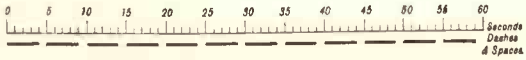


Fig. 5.—GRAPHIC REPRESENTATION OF DISTRESS CALL.

The upper scale represents seconds and the lower represents dashes and spaces.

closes the clutch magnet circuit, and the motor commences to rotate the contact cam towards the contact brushes which complete the various circuits.

Should the signal *not* be a distress call, that is, if the first " dash " is not of correct time duration—within certain specified limits of error—the clutch magnet circuit is broken and the cam turns back under the action of a spring to its starting or datum position.

The Spacer Relay

If, however, the signal has the correct time duration, the spacer relay then takes care of the " space," and provided this is of correct duration it prevents the release action of the clutch and keeps the clutch driving the cam until the second " dash " is received, this being repeated until three consecutive dashes have been received—by which time the cam has advanced sufficiently to close the alarm bell circuit and set the alarm bells ringing, and they then continue to do so without further regard to the selector.

Sorting Out the Signals

When the alarm signal is received the clutch mechanism holds the cam in engagement with the clutch and enables the motor to rotate the cam continuously until the bell contact is closed and the alarm bell sounded. The cam remains in the stop, or bell ringing position until it is released by the operator coming on duty.

If Morse and alarm signals are superposed the cam advances correctly and sounds the alarm unless interference is exceptionally severe, in which case the cam returns to the datum position and responds at a later part of the same distress signal.

If a continuous " dash " signal is received the cam advances about a third of its travel, then falls back to the datum position and repeats these movements.

When Morse signals are received the cam only makes small movements, never more than a tenth of the amount required to sound the alarm.

Efficiency

The efficiency of the auto-alarm is such that it will accept a dash as being intended to have a four-second duration if in fact it has a duration of more than three or less than five seconds. Similarly, it accepts as a one-second space any space of more than one-fifth second and less than two seconds.

Mechanical Judgment

It operates only at the end of the third consecutive dash if it has also accepted the intervening spaces. The mechanism judges each dash and each space on its merits, and within the stated limits accepts the signal if all the dashes are too long or too short, or the errors are jumbled together. This is necessary as a distressed ship may have to send out the distress call by hand with very indifferent means of measuring time duration, particularly if the wireless equipment had been damaged.

THE TUNED ANODE THREE

By EDWARD W. HOBBS, A.I.N.A.

THIS set can be built for a total outlay of about 50s., including valves, batteries, loud speaker and all materials. Despite this very low cost, the receiver is quite efficient, has a pleasing tone, and brings in a reasonable number of stations, foreign stations included.

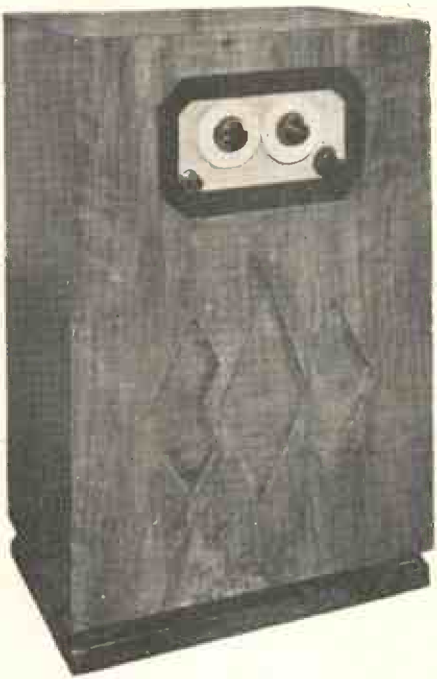


Fig. 1.—THE COMPLETED SET.

Features of the Circuit

The circuit, Fig. 2, provides for a stage of tuned high-frequency amplification, coupled by a modern arrangement of the tuned anode system to an efficient detector valve, transformer coupled to a power output valve. Dual range switching is combined with the on-off switch. The aerial is auto-transformer coupled to the aerial tuning coil, and this in conjunction with the tuned anode circuit, with capacity reaction, gives sufficiently high degree of selectivity without loss of tonal quality.

Components and Materials

Coils.—2 " Becol " coil formers No. 12, each $2\frac{3}{8}$ inches diameter, $2\frac{1}{4}$ inches long. (*British Ebonite Company.*)

1 oz. each No. 26, No. 32, No. 36 D.S.C. wire. (*Lewcos.*)

4 small terminals and nuts.

Variable Condensers.—2 Bakelite dielectric tuning condensers ·0005 mfd. with knob. (*Telsen.*)

1 Reaction condenser. Bakelite dielectric ·0003 mfd. with knob. (*Lissen.*)

Valve Holders.—3 rigid 4-pin holders. (*Telsen.*)

Fixed Condensers.—1 with G.L. clips, ·0001 mfd. (*Telsen.*)

1 ·01 mfd., type 34. (*T.C.C.*)

Grid Leak.—1, 1 megohm. (*Lissen.*)

Transformer.—1 " Ace," L.F. ratio 5 to 1. (*Telsen.*)

Valves. — 2 Universal Bivolt. (*Dario.*)

1 Super-power Bivolt. (*Dario.*)

Batteries.—L.T. accumulator 2 volt, type D.T.G. 20 A.H. (*Exide.*)

H.T. 99 volt, type H1005. (*Drydex.*)

G.B. 6 volt, type H1040. (*Drydex.*)

Loud Speaker.—No. W181 complete. (*Telsen.*)

Terminals.—2, marked A and E respectively. (*Belling-Lee.*)

Battery tags, 2 marked L.T. + ; L.T. − respectively. (*Belling-Lee.*)

Wander Plugs.—1 each marked G.B. − ; H.T. + 1 ; H.T. + 2 ; H.T. + 3. (*Belling-Lee.*)

Fuse.—1 " Wanderfuse." (*Belling-Lee.*)

Battery Connector. — Flexible type. (*Bulgin.*)

Wiring.—2 coils " Glazite." (*Lewcos.*)

2 Yards " Lewcos flex." (*Lewcos.*)

Switch.—1 On-off push-pull type. (*Lotus.*)

Hard brass strip, $\frac{1}{4}$ inch wide, No. 20 gauge, 14 inches long.

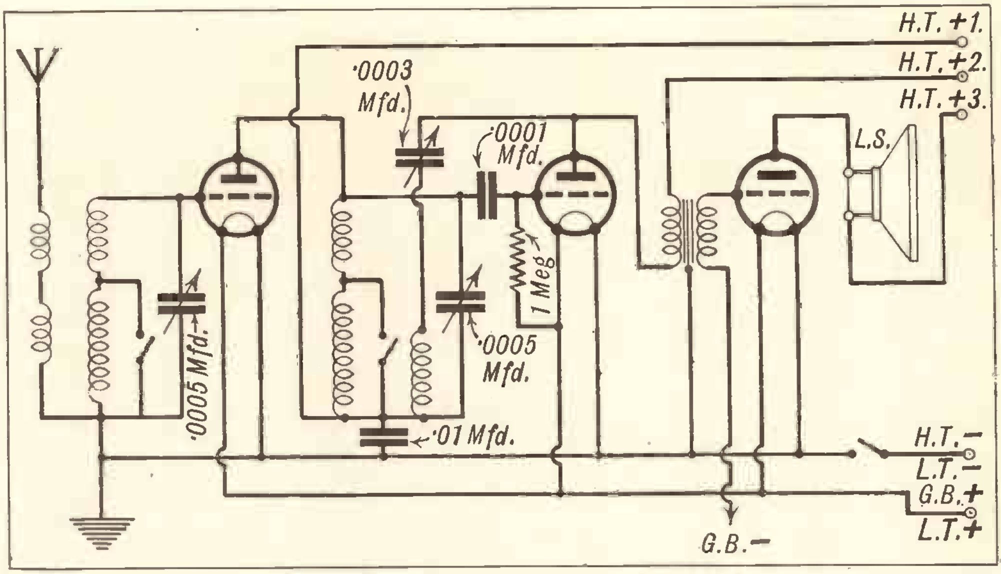


Fig. 2.—CIRCUIT OF THE TUNED ANODE THREE.

Two tuned circuits ensure selectivity, while a power output valve provides adequate volume.

1 Dozen $\frac{3}{8}$ inch by No. 4 brass round-head screws.

$1\frac{1}{2}$ Dozen $\frac{5}{8}$ inch by No. 4 brass round-head screws.

Panel.—Plywood, 12 × 6 × $\frac{1}{8}$ inch.

Base.—Deal, 12 × 8 × $\frac{1}{2}$ inch.

Switch Base.—Deal, $2\frac{1}{2}$ × $1\frac{1}{4}$ × $\frac{3}{8}$ inch.

Coil Block.—Deal, $1\frac{5}{8}$ inches diameter by $\frac{3}{8}$ inch thick.

Cabinet.—Plywood, $\frac{1}{4}$ inch thick, 2 side pieces 22 × 10 inches; 3 pieces 16 × 10 inches; 2 pieces, 22 × 16 inches.

Plinth.—Deal, 2 × 1 inch × 4 feet long; 1 × 1 inch × 4 feet long.

Fillet.—Deal, $\frac{1}{2}$ × $\frac{1}{2}$ inch; 8 feet.

Gauze.—1 Square foot speaker fret gauze.

First wind the Aerial Tuning Coil

Begin by winding the coils as described on pp. 381 to 392 of COMPLETE WIRELESS. The windings should be as follows. Aerial coil medium wave winding consists of forty-two turns of No. 26 D.S.C. wire; the long-wave winding consists of thirty turns each of No. 32 D.S.C. in four slots, 120 turns in all. The aerial coupling winding consists of seven turns of No. 36 D.S.C. wire wound close against the

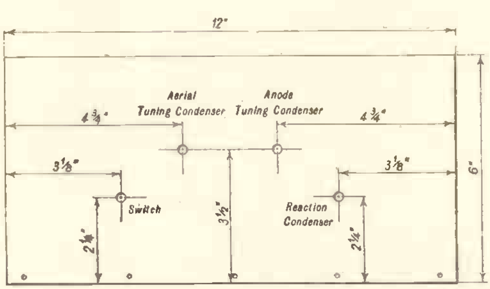


Fig. 3.—PANEL LAYOUT.

Here are given the spacings of the holes in the front panel for the condensers and switch, as seen from the front.

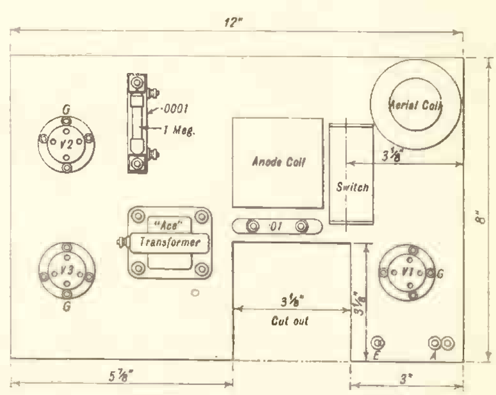


Fig. 4.—LAYOUT OF BASEBOARD.

medium winding and seven turns wound in the reaction slot.

What to do with the Ends

The ends of the various windings on aerial coil should be dealt with as follows.

Start of medium wave winding to grid of first valve; end of this winding to be joined to start of long-wave winding and left long enough to reach to switch. End of long-wave winding connects to switch. Start of aerial coupling winding connects to "aerial" terminal end of this winding to switch.

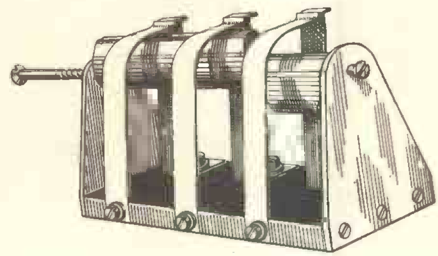


Fig. 5.—CONTROL SWITCH.

This home-made switch controls wave range and combines an "on-off" movement.

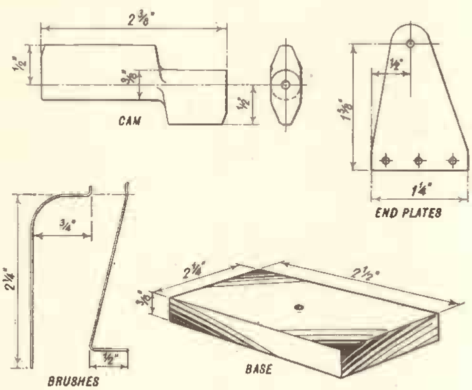


Fig. 6.—PARTS OF THE SWITCH.

Here are shown the separate parts of the control switch.

Now wind the Anode Tuning Coil

The anode tuning coil windings consist of forty-two turns of No. 26 D.S.C. for the medium wave; thirty turns of No. 32 D.S.C. each in four slots for the long wave; reaction winding forty turns of No. 36 D.S.C. All wound in the same direction.

The start and finish of the reaction winding should be connected to terminals, the start of medium wave winding should be connected to a terminal, the end of this winding and start of long-wave winding should be fastened together and left long enough to connect to switch.

The end of long-wave winding should be connected to a terminal.

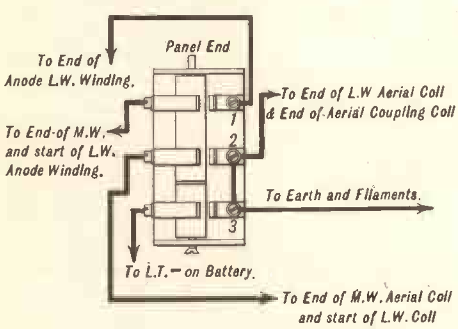


Fig. 8.—SWITCH CONNECTIONS.

Plan view of switch showing the various connections.

Mounting the Components

Drill the panel for the components as shown in Fig. 3; next prepare the base-board, noting the part cut away at the back for the accumulator, then screw the panel to the front of the base and mount the components as shown in Fig. 4, but do not fix the two coils until the switch is made and fitted.

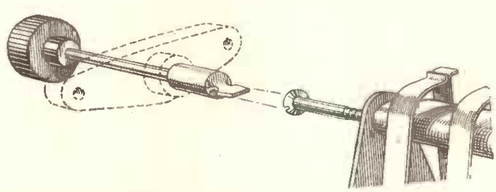


Fig. 7.—SWITCH HANDLE AND CONNECTOR.

The central spindle of the "on-off" switch is filed down to a screw-driver shape to engage the slot in the end of the cam spindle.

The Control Switch

The control switch is shown complete in Fig. 5 and the separate parts in Fig. 6; it is easily made, consisting of a wooden base with uprights at each end.

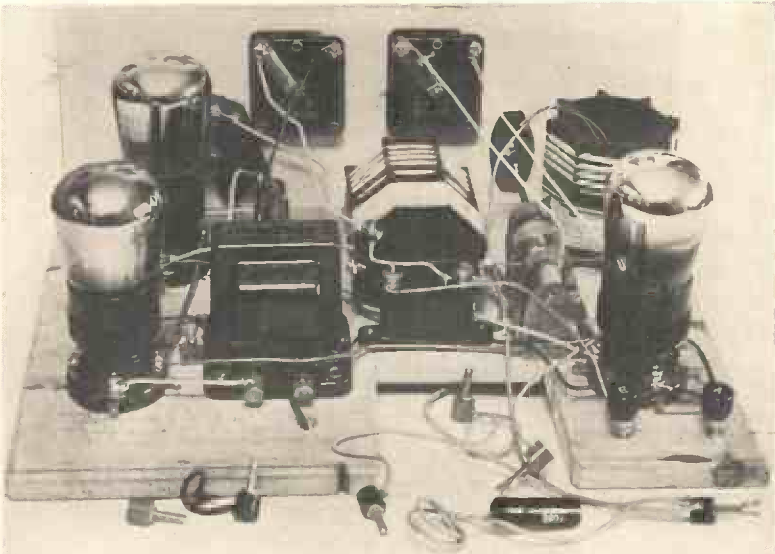


Fig. 9.—THE SET WIRED UP IN READINESS TO PLACE INSIDE CABINET.

The switch cam is a piece of ebonite or wood shaped as shown in Fig. 6, and supported by one long screw about $2\frac{1}{4}$ inches long, and one short screw, both passed through holes in the uprights.

Next bend the brass strips or brushes to shape and screw them to the base. They should be adjusted so that they press against each other at the tops when the cam is upright.

When the cam is turned to the left, as seen from the front, the back pair of contacts should separate. When the cam is vertical all contacts should be closed, but when turned to the right the first two pairs of contacts should open.

Switch Handle

The switch handle is made by converting the on-off switch by first

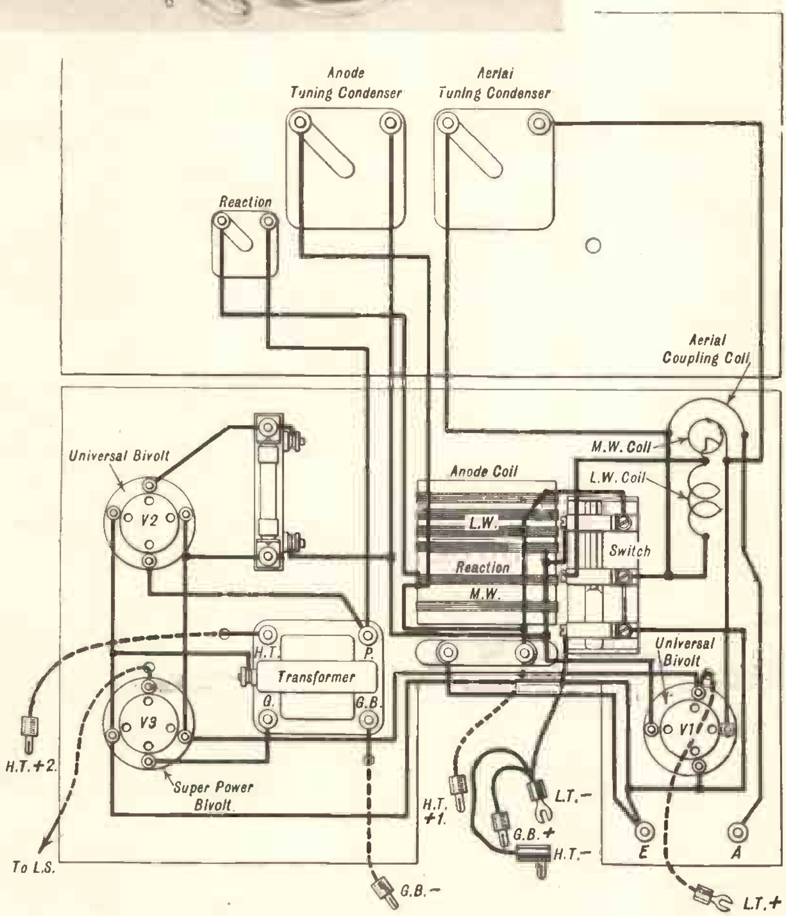


Fig. 10.—POINT TO POINT CONNECTIONS.

removing the two contact blades, then filing the knob to form a flat end shaped like a screw-driver—as in Fig. 7—so that it will engage with the slot in the end of the long screw, which projects from the cam, on the switch. Fit a small collar or tube over the push-pull switch rod to prevent it moving backwards and forwards.

Now screw the switch in place, adjust it carefully to see that the contacts open and close properly, if necessary putting very thin rubber bands across each to hold them in close contact. Note that "hard spring" brass must be used, not ordinary soft brass.

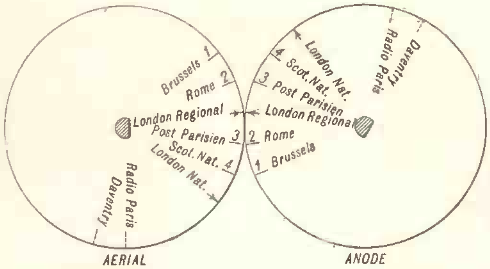


Fig. 11.—The Tuning Dials.

These dials simplify tuning. All that has to be done is to turn both until the corresponding marks are opposite. Many other stations than those named can be received on the set.

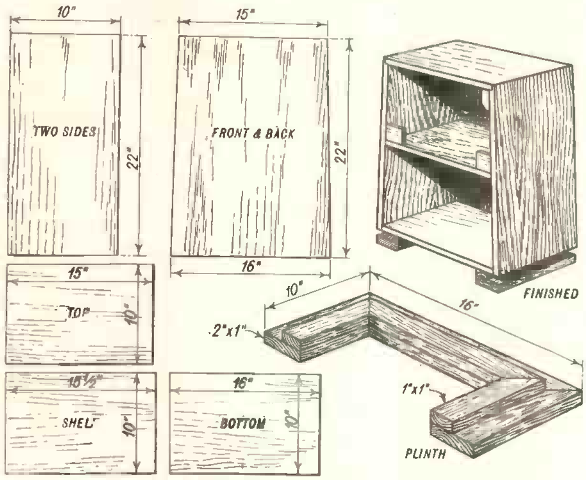


Fig. 12.—Cabinet Details.

Shapes and dimensions of the cabinet with a sketch of the finished cabinet from the back and a section of the plinth.

the coils are fixed and greatly facilitates the work.

The detail wiring of this part is clearly shown in Fig. 8; take great care to isolate the connections to No. 1 contacts, because this contact is in the H.T. plus circuit and must not be connected directly to earth. Any type of switch that normally would suit a pair of dual-range coils by connecting both to earth must not be used. Note carefully that the ·01 mfd. condenser is provided especially to prevent short circuiting and to improve the performance of the set.

Having connected the coils to the switch, complete the wiring according to the diagram in Fig. 10 and the view, Fig. 9, of the complete set.

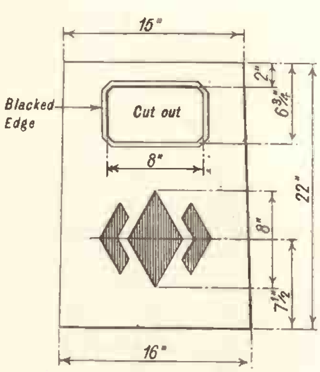


Fig. 13.—Detail of Cabinet Front.

Showing panel opening and loud speaker fret.

Wiring the Set

The most convenient way to wire this set is first to connect the various ends of the coil windings to the switch and to the other components; this can be done before

Point to Point Connections

After connecting the switch and coils as already described, proceed as follows.

Connect switch contact No. 3 to filament terminal of V1, thence to E terminal, thence to a filament ter-

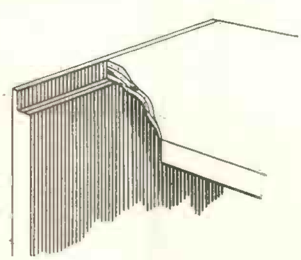


Fig. 14.—Corner Joint.

All corner joints are rebated or housed as here shown.

minal of V2 and V3 and to earthing terminal on the "ace" transformer. Connect second contact No. 3 of switch by a flexible wire to L.T. minus battery tag.

Connect L.T. plus battery tag to a flexible wire, connect this wire to second filament terminal on V1, thence by "Glazite" wire to the second filament terminals on V2 and V3, and thence to free end of grid leak.

Grid of V1 to fixed plates of aerial tuning condenser; moving plates of same to No. 2 switch contact.

Connect anode tuning condenser, fixed plates to grid condenser, start of medium wave coil windings and anode of V1; moving plates to end of reaction winding and earthing condenser.

Reaction condenser, fixed plates to anode of V2 and "P" of "Ace" transformer; moving plates to start of reaction winding.

Connect grid of V2 to grid condenser; grid of V3 to "G" of "Ace" transformer.

Connect free terminal of earthing condenser to earth terminal.

Battery Connections

Connections by flexible wires should be made as follows. "H.T. plus 1" to earthing condenser and coil; "H.T. plus 2" to "H.T." on "Ace" transformer; "H.T. plus 3" to loud-speaker terminal marked +. "G.B. minus" to "G.B." on "Ace" transformer.

This completes the wiring, which must be very carefully checked over by the circuit diagram and the wiring diagram to make sure all is correct. Then connect the "Wanderfuse" in the H.T. minus lead, connect this lead also to G.B. plus and L.T. minus. Connect up the batteries, putting H.T. + 3 to 99 volts, H.T. + 2 to 90 volts, H.T. + 1 to 72 volts, and G.B. — to 3 volts negative.

Insert the valves, connect to aerial and earth, then switch on and tune in the local station. The set completely wired is shown in Fig. 9 together with the control switch.

Fig. 15.—BACK VIEW OF SET.

The set rests on bearers and the batteries on the shelf underneath.

Making the Cabinet

The woodwork on the cabinet is quite simple, the details and shapes of the parts are shown in Fig. 12, while Fig. 13 gives details of the front panel and loud-speaker fret, which should be cut out with a fret saw in the usual way.

Joints at the corners are made on the rebate or "housed" system, as shown in Fig. 14, and securely glued together. The front is similarly fixed. Fillets are then glued and pinned inside the case to support the battery shelf and two bearers and a front fillet fitted for the baseboard to rest upon.

Fillets are also glued around the inside ¼ inch away from the edge to support the back, which fits inside the case and can be screwed to the fillets. The plinth is built up, mitred at the corners and glued to the underside of the cabinet and stained black, the remainder being stained walnut colour and polished or varnished.

The loud speaker is screwed in place over the fret after the gauze has been glued into position.

A view of the complete set seen from the back is given in Fig. 15, which will make all details clear.

RECEIVER DESIGN

By L. D. MACGREGOR

WHEN contemplating the design of a radio receiver the first consideration which occurs to one is that it must be constructed to fulfil certain requirements, and what will these requirements be? There are several factors which together constitute these requirements, and these may be tabulated as below. They have been chosen and described as they are so as to constitute a link between the technical and non-technical man which will be readily understood by both and will enable the latter to more easily describe his wants to the former.

(1) Power output.
(2) Range or sensitivity.
(3) Selectivity.
(4) Simplicity of control.
(5) Quality of reproduction.
(6) Consumption or operating cost.
(7) Cost of the receiver.

Although these have been tabulated in the above order, it is not intended that this order be an indication of the importance of the factors as, according to individual opinions, one or other of the factors will be given predominance over the remainder.

These factors may again be subdivided as below :—

1. Power Output

(*a*) Small halls, concerts, etc.
(*b*) To feed several loud speakers.
(*c*) For general domestic use.
(*d*) Portables.

2. Range or Sensitivity

(*a*) Local stations.
(*b*) High power British and European.
(*c*) European.
(*d*) Transatlantic.
(*e*) World reception.

3. Selectivity

(*a*) Good.
(*b*) Very good.
(*c*) Best possible.

4. Simplicity of Control

(*a*) Minimum possible controls, such as pre-tuned switch control.
(*b*) Single dial tuning, volume control, wavechange switch and tone control.
(*c*) As in (*b*), but with reaction control.
(*d*) Two dial tuning, volume, wave-change, tone control.
(*e*) As in (*d*), but with reaction control.

5. Quality of Reproduction

(*a*) Good.
(*b*) Very good.
(*c*) Best possible.

6. Consumption or Operating Cost

(*a*) Immaterial.
(*b*) Moderate.
(*c*) Lowest possible.

7. Cost

(*a*) Immaterial.
(*b*) Moderate.
(*c*) Lowest possible.

It will be appreciated that the majority of the aforementioned factors with their subdivisions are, to a certain extent, interdependent, but at the same time they will have to be considered from the aspect shown when commencing the design.

1. POWER OUTPUT

Consideration of the requirements in this direction will determine the output stage of the apparatus.

(a) Small Hall, Concerts, etc.

An output stage capable of delivering from 5 to 15 or even 20 watts, depending upon the size of the building, will be required. In the latter case it would be advisable to couple the receiver to a separate amplifier capable of delivering the energy required. When estimating the output required it should be borne in mind that the audience has a definite sound-absorbing value and an amplifier that will easily fill an empty hall will not sound anything like as loud when the hall is filled with people. In a small provincial cinema an output of 10 watts was found to be only just sufficient.

(b) To Feed Several Loud Speakers

From 2 to 5 watts output would be required for this purpose, and in arriving at the estimated value account should be taken of the sensitivity of the speakers which will be used.

(c) For General Domestic Use

According to requirements any value from ·3 watt to $2\frac{1}{2}$ watts may be necessary. In the average home an output stage capable of delivering 1 watt is ample.

(d) For Portable Receivers

Owing to the necessity of employing extra valves in order to compensate for loss of range when using a frame aerial, and again, owing to the necessity of employing small H.T. batteries, the output from a portable is limited to less than $\frac{1}{2}$ watt—generally about 300 to 350 milliwatts are considered to be ample output for this type of receiver.

When considering the output required it should be borne in mind that the figures given here are for a maximum undistorted output with permissible 5 per cent. second or third harmonic distortion. Further, it should be remembered that, as a general rule, reed loud speakers are more sensitive than permanent-magnet moving-coil speakers, and, when estimating the outputs given above, the latter type of speaker was considered.

2. RANGE OR SENSITIVITY

This will depend upon the number of high-frequency stages and the efficiency of the stages. In cases where cost is an important factor the ordinary H.F. valve aperiodically coupled may be used. For best results the popular screened-grid valve should be employed.

(a) Local Stations

As a general rule a detector valve followed by suitable L.F. stages will suffice for most requirements.

(b) High Power British and European

A single high-frequency S.G. stage followed by a detector and one or two L.F. stages will suffice for this range.

(c) European Stations

Two or three stages of S.G. high-frequency amplification, followed by the usual detector and appropriate L.F. amplification, are required.

(d) Transatlantic Reception

While this may be effected by receivers of (*c*) group and occasionally by those of (*b*) group, for the most satisfactory results a receiver of the superheterodyne type is required.

(e) World Reception

This will necessitate a superheterodyne receiver to operate on short wavelengths with facilities for changing to the medium and possibly the long wavebands.

The range of any given receiver is dependent, to an extent, on the local and atmospheric conditions, and, further, the amplification between stages will have a considerable bearing upon results. Under average conditions the foregoing figures are a fair estimate of the requirements in this direction.

3. SELECTIVITY

This will be, to an extent, relative to the type of receiver, as obviously the same amount of selectivity cannot be obtained with a detector L.F. as with a 2 H.F. detector L.F. receiver. The definitions below will therefore be relative.

(a) Good

In the case of a detector with no H.F. stages a loose coupling may be considered good, but where one or more H.F. stages are used a band-pass input or its equivalent will be necessary.

(b) Very Good

Band-pass with detector only and in the case of H.F. stages one or more tuned circuits.

(c) Best Possible

Band-pass superheterodyne or receiver employing the " Stenode " principles.

4. SIMPLICITY OF CONTROL

(a) Minimum Possible Controls—Pre-tuned Circuits

Undoubtedly the minimum possible controls are where pre-tuning has been arranged and the stations required are obtained by means of switches which switch the receiver "on and off" at the same time. It may be necessary to fit a volume control and possibly a tone control to suit the individual requirements.

(b) Single Dial Tuning, Volume Control, Wavechange and Tone Control

This will call for ganged tuning condensers. Either a superheterodyne or a multi-stage H.F. receiver with possibly variable-mu valves are indicated by the volume control. Perhaps to this could be added the neutrodyne receiver, but this is not in such favour nowadays.

(c) As in (b) but with Reaction

A three- or four-valve receiver having one stage of H.F. amplification would come under this heading.

(d) As in (b) but with Two Tuning Dials

This would cover the two-dial superheterodyne and other receivers where ganging has not been effected.

(e) As in (d) but with Reaction additionally

No comment is necessary in this case.

Tone Control

Tone control, although added here, is optional. In the case of single detector and L.F. stages, controls would be (*a*) as above; (*b*) band-pass input, ganged, no reaction; (*c*) as in (*b*) with reaction; and for single tuning condenser only, this would come under (*e*).

5. QUALITY OF REPRODUCTION

This subject is, to an extent, controversial, and in subdividing this heading it was decided to consider the total effective range of the speakers. From a commercial point of view it will be the customer who will make the final decision.

(a) Good

The quality, such as would be obtained with a really good reed loud speaker. In this case there will be a falling off at the lower register and over 5,000 cycles in the upper register. Types classified in order of cost:—

Electrostatic cheap models.	Plain flat reed.
	"Vee" and Differential.
	Balanced armature, Inductor.
	Special scientifically built reed movements.

(b) Very Good

Results as obtained from a good permanent magnet moving-coil, a super-quality reed speaker, inductor or electrostatic model. Lower or upper register improved and total register possibly extended. Cheap dual loud speakers would be included providing results came under this heading.

(c) Best Possible

The best commercially available covering the maximum audible range. If moving-coil it would have to be energised to obtain the maximum necessary flux density in the gap. Possibly dual loud speakers—moving-coil and electrostatic or balanced moving-coil—would best justify this title.

It has been assumed in subdividing quality that the output fed to the loud speaker is in keeping with the quality subdivisions.

6. CONSUMPTION OR OPERATING COST

(a) Immaterial

In the case of those who have mains supply this will indicate that these may be used to the full extent. In the event of no mains supply being available super-capacity H.T. batteries or H.T. accumulators may be used for supplying the receiver.

(b) Moderate

In the case of mains driven receivers this may be taken to indicate an input of not more than 100 watts—more generally 60 watts. In the case of battery supply

CHART OF TYPES OF RECEIVERS

Description of Receiver	Cons. Watts or M.A.	Output in Watts Approx.	No. of Valves	Power 1 A–Small Hall B–Several speakers C–Domestic D–Portable	Range 2 A–Local B–H.P. do. and European C–European D–Transatlantic E–World reception	Selectivity 3 A–Good B–Very good C–Best poss.	Controls 4 A–Min. poss. preset B–Single dial C–Reaction dial D–2 dials E–2 dials reaction	Quality 5 A–Good B–Very good C–Best poss.	Consumption 6 A–In material B–Moderate C–Lowest poss.	Cost 7 A–Immaterial B–Moderate C–Lowest poss.
Single pentode. Battery operated	6 m.a.	0·2	1	D	A	A	E	A	C	C
Simple detector and 1 L.F. Battery	8 m.a.	0·4	2	C	A	A	E	A	C	B
Band-pass input, det. and 1 L.F. Mains	20 w.	1·0	2	C or B	A to B	B to C	B to C	B	C	B
Band-pass input, det. and 2 L.F. Mains	30 w.	1·5	3	B	A to B	B to C	B to C	B	B	B
Det. and 2 L.F. (short wave). Battery	12 m.a.	0·4	3	C	D	B	C	A	B	C
Band-pass input, S.G. H.F., pen. det. Mains	30 w	0·5	2	C	B	B	C	B	B	B
S.G. H.F., det. and 1 L.F. Battery	10 m.a.	0·4	3	C	B	A	E	A	C	C
Band-pass input, S.G. H.F., det., L.F. Battery	10 m.a.	0·4	3	C	B to C	C	C	B	C	B
2 S.G. H.F. and pen. det. amplifier. Mains	60 w.	0·75	3	C	B to C	B	B	B	B	B
S.G. H.F., det. and 2 L.F. (short wave). Battery	12 m.a.	0·4	4	C	D to E	B	E	B	B	B
Band-pass input, 2 S.G., det. and L.F. Mains	50 w.	1·0	4	B	C	B	B	B	B	B
Band-pass input, 2 S.G., det. and 1 L.F. Mains	60 w.	2·0	5	B	C to D	B	B	B	B to A	B to A
S.G. (band-pass input and coupling) det. and 2 L.F. Mains	60 w.	2·0	4	B	C to D	A	B	A	B	B
Do., with 1 aperiodic H.F., det. and 3 L.F., push-pull. Mains	200 w.	5·0	6	B to A	C to D	A	B	B	A	A
2 S.G. HF. det. and 2 L.F. (band-pass input and with short-wave super-het. adaptor. Mains	80 w.	2·0	6	B	C to E	B to C	B to E	B	B	B
Small super-het. with S.G. H.F. stage, det., 2 intermediate, det., and 1 L.F. Mains	40 w.	0·5	6	C	D	C	B	B	C	C
3 S.G. H.F., det., 2 L.F. band-pass input and carefully balanced amplifier of generous proportions. Mains	150 w	10	6	A	D	B	B	C	A	A
Mains super-het. with all improvements, heavy output, medium wave lowest, stenode principles, balanced amplifier.	200 to 300 watts	10	8 or 9	A	D	C	B	C	A	A
Do., with arrangement for short wave work and pre-set tuning	”	”	”	A	E	C	A	C	A	A
Simple 2-valve S.W. receiver. Battery	7 m a.	0·4	2	D	D	B	E	A	C	C

being the only supply available, 12 to 15 milliamperes may be considered a reasonable figure.

(c) Lowest Possible

If mains driven the input should not exceed 30 watts, and for battery supply no more than 10 milliamperes (and preferably about 7 m.a.) may be allowed.

The consumption will, of necessity, be relative to the factors previously mentioned, but the above figures constitute a general average.

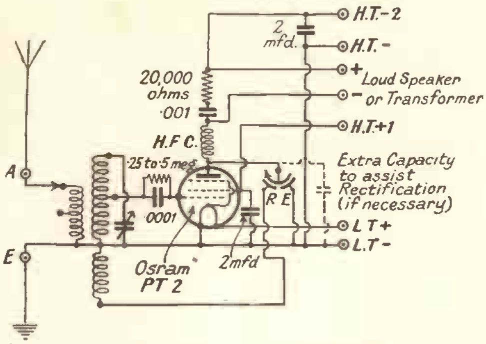


Fig. 1.—A Single Valve Circuit.
Showing the amplifying properties of a detector valve suitable for local reception.

7. COST

These figures will vary with the other requirements and with the quality of the material used, and in view of this and other factors governing cost, which change from time to time, it is not proposed to give figures for the subdivisions under this heading.

From the foregoing definitions of the salient points of receivers it will be possible to classify various types, and an attempt at this has been made in the accompanying chart. It will be appreciated in view of the factors being to an extent interlinked that there is a certain amount of latitude which will have to be made to meet special cases. It is known, for example, that, given certain conditions, transatlantic reception is possible on the medium waveband with a detector and two low-frequency stages. On the short waveband this is a favourite combination, nevertheless, few people would care to manufacture and sell such a receiver to the public with the assurance of transatlantic reception under all circumstances on the medium waveband.

HOW THE RADIO RECEIVER IS BUILT UP

The average radio receiver may be considered as being built up of two main sections which are linked together by the detector. The first section comprises all which precedes the detector valve and may include its grid circuit—this we will designate the H.F. section. The second section will comprise all which follows the detector valve, including its anode circuit—this may conveniently be termed the L.F. section.

These two sections may be subdivided into amplifying stages, and for this purpose we will consider that an amplifying stage is one which has been introduced to effect amplification other than that obtained from the aerial coils or the detector valve.

An interesting circuit illustrative of detector amplification is shown in Fig. 1, and has given quite good results on local reception.

AMPLIFYING STAGES—L.F.

An amplifying stage may be defined as from the grid input of one valve to the grid input of the next valve, and it is not proposed to deal with the output stage, this having been dealt with in the article on "How to Match Loud Speakers to the Output Stage" (see p. 707).

It remains, then, to consider the case first of L.F. coupling between valve and valve, such as would occur in a two-stage L.F. amplifier section of a receiver.

The various types of coupling employed between two low-frequency valves are described below.

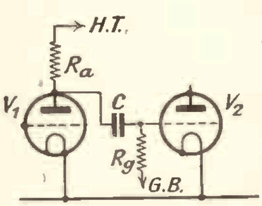


Fig. 2.—Resistance Capacity Coupling.

Resistance Capacity Coupling.—1

With this form of coupling the amount of amplification between V_1 and V_2 will depend upon the coupling combination, R*a*, C, and R*g*. The A.C. resistance of V_1—which we will call R*p*—and the valve magnification factor, μ will

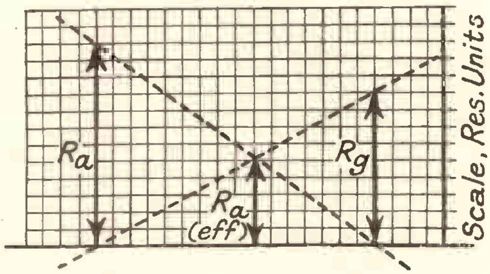


Fig. 3.—Graphical Method of Adding Two Resistances in Parallel.

$$\text{R}a\ (\text{effective}) = \frac{\text{R}g\ \text{R}a}{\text{R}a + \text{R}g}$$
$$= \frac{1}{\text{R}g} + \frac{1}{\text{R}a}.$$

also have a considerable bearing upon the results.

The simplest formula for this stage is

$$\text{Amplification A} = \mu \frac{\text{R}a}{\text{R}p + \text{R}a} \quad . \quad (1)$$

A more comprehensive formula is,

$$\text{A} = \mu \frac{\text{R}a\ (\text{effective})}{\text{R}p + \text{R}a\ (\text{effective})} \quad . \quad (2)$$

where we may consider R*a* (effective) as being at high audible frequencies equal to

$$\text{R}a\ (\text{effective}) = \frac{\text{R}g\ \text{R}a}{\text{R}g + \text{R}a} \quad . \quad (3)$$

In this case the effect of the coupling capacity C is negligible.

At the lower frequencies, where C is not negligible, we may consider that

$$\frac{1}{\text{R}a\ (\text{effective})} = \frac{1}{\text{R}a} + \frac{1}{\sqrt{\text{R}g^2 + \left(\frac{1}{w\text{C}}\right)^2}} \quad . \quad (4)$$

The proportion of the signal transferred to the grid of V_2 from across R*a* is equal to

$$\frac{\text{R}g}{\sqrt{\text{R}g^2 + \left(\frac{1}{w\text{C}}\right)^2}} \quad . \quad (5)$$

A graphical method of obtaining the value of R*a* (effective) of (3) is shown in Fig. 3, and a curve showing the percentage value of the valve magnification factor, μ, for various ratios of R*a* to R*p* is given in Fig. 4. This will hold good for ratios of R*a* (effective) to R*p*.

Effect of Using too large a Value of R*g*

If the value of R*g* is too large there will be a risk of the valve, V_2, becoming paralysed by a strong signal due to the fact that the momentary charge on its grid cannot leak away fast enough through R*g*. This is technically known as "blocking," and to avoid this unpleasant effect it is generally considered unwise to endeavour to obtain more than 90 per cent. efficiency at 50 cycles.

If we multiply the value of the coupling condenser by that of the grid resistance we obtain a value equal to R × C. This value, R × C, is called the time constant.

Some authorities state that a value of time constant of ·0065 should not be exceeded if " blocking " is to be avoided. Others give the figure as ·01, and some as high as ·025. As long as " blocking " does not occur the highest value may be used, but should it occur, then the value of the grid resistance will have to be lowered, and possibly the value of the coupling condenser. Certainly the RC product of the two will have to be lowered.

How to arrive at the Correct Value for the Coupling Condenser

At the lower frequencies it will be seen that the voltage across C and R*g* in series is not the same as across R*g* (5), and that only a fraction of this will be impressed upon the grid of V_2. The

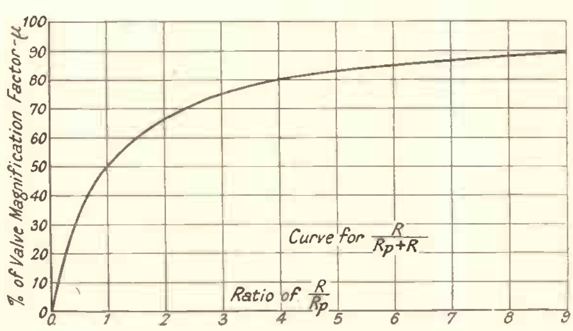


Fig. 4.—Curve showing Percentage Value of the Valve Magnification Factor μ for Various Ratios of R*a* to R*p*.

value of the coupling condenser, C, may be obtained from the formula :—

$$C = \frac{n}{wRg\sqrt{1 - n^2}} \quad . \quad (6)$$

where $w = 2\pi \times$ the frequency (f). C = coupling condenser in farads. Rg grid resistance in ohms. n = the fraction of full amplification required at the frequency f.

For example, it is desired to obtain 80 per cent. of the full amplification at 50 cycles, using a grid leak of 1 megohm. What value of C is required ?

$$C \text{ fds.} = \frac{\cdot 8}{2\pi \times 50 \text{ R}g\sqrt{1 - \cdot 8^2}}$$

$$= \frac{\cdot 8}{314 \times 10^6\sqrt{1 - \cdot 64}}$$

$$= \frac{\cdot 8}{314 \times 10^6\sqrt{\cdot 36}}$$

$$= C \text{ mfds.} = \frac{\cdot 8}{198\cdot 4} = \cdot 0043 \text{ mfds.} \quad \textit{Answer.}$$

Approx. Values of C for % Efficiency at 50 Cycles Frequency.		Value of Resistance, Rg.
80 %.	90 %.	Rg Megohms.
·0043 mfd.	·0066 mfd.	1 megohm
·00215 ,,	·0033 ,,	2 ,,
·00145 ,,	·0022 ,,	3 ,,
·0086 ,,	·013 ,,	·5 ,,
·0172 ,,	·026 ,,	·25 ,,
·0430 ,,	·065 ,,	·1 ,,

Now the values of C and of Rg for the same percentage are in inverse proportion, thus, for a 2-megohm value of Rg, C would be ·00215 mfds., and for a ·5 megohm C would be ·0086 mfds. These values would be for 80 per cent. efficiency at 50 cycles.

For 90 per cent. efficiency with 1 megohm resistance at 50 cycles C would require to be ·0066 mfd.

As a general rule the anode resistance is about five times the A.C. resistance of the valve—such A.C. resistance value being taken with the grid at zero volt.

Suitable Values for a Simple Case

Let us consider suitable values for a simple case. A valve such as the Mazda H.L.2, with an A.C. resistance of 21,000 ohms and a magnification factor of 31, is required to be resistance coupled to another valve. The input to this valve will be small—of the order of ·25 volt either way, therefore bias will not be required as grid current does not start till ·3 volt positive. The makers recommend an anode resistance value of 100,000 ohms. What magnification can we expect, and what value of coupling condenser and leak would be necessary to keep the amplification at 50 cycles up to 90 per cent. of the maximum amplification ?

The ratio of anode resistance to valve resistance is $\frac{100 \times 10^3}{21 \times 10^3}$, or nearly 5 to 1. Looking up the chart, we see that this corresponds to 83 per cent. of the valve magnification factor μ. The value of μ is 31, therefore the most we can hope to attain is $\frac{31 \times 83}{100} = 25\cdot 73$. Bearing in mind that the grid resistance is in shunt across the anode resistance we find that if we use a 1 megohm leak the effective value of the anode resistance will be lowered 10 per cent. Referring again to the chart we find that this will lower the percentage amplification to 81 per cent. This is not so bad, as it leaves us with a

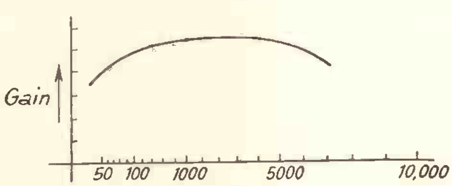


Fig. 5.—Chart showing Fair Frequency Characteristic of an Amplifier.

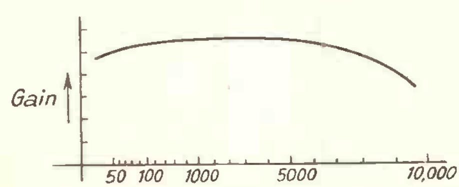


Fig. 6.—Chart showing Good Frequency Characteristic of an Amplifier.

value of 24 for the magnification. The coupling condenser value we can work out from formula 6, or take from the table. For a 1 megohm resistance this will be ·0066 for 90 per cent. efficiency at 50 cycles.

This gives us an overall magnification of 24 with a value of 21·6 magnification at 50 cycles.

Allowing our input as ¼ volt swing each way we should obtain 6 volts peak, or 4·2 volts R.M.S. on the grid of the succeeding valve, the voltage falling to 5·4 peak or 3·7 R.M.S. at 50 cycles.

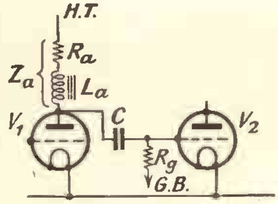


Fig. 7.—Choke Capacity Coupling.

percentage efficiency at 50 cycles.

The wiser plan would be to use a stage of grid-choke or parallel feed coupling and arrange to compensate for the loss. Still, if expense was of small consideration, this result could be achieved with resistance coupling in the manner stated.

A Practical Tip

Where possible check the anode volts, the A.C. resistance and the magnification factor of the valve under working conditions. This will obviate much error. The A.C. resistance and the anode volts for a given resistance, together with the magnification factor may all be obtained by the method described in "How to Match Loud Speakers to Output Valve." A set of curves of anode current-anode volts should be constructed if it is desired to do the job properly.

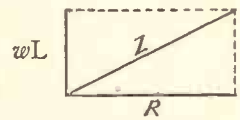


Fig. 8.—Showing Impedance of Circuit containing Resistance R and Inductance L at Frequency $\frac{w}{2\pi}$.

Two Stages of Resistance Coupling

When two stages of resistance coupling are used remember that, if 90 per cent. efficiency at 50 cycles is allowed for each, the efficiency for the *two* stages at 50 cycles will not be 90 per cent., but rather 90 per cent. of 90 per cent., which is 81 per cent. Similarly with three stages, when the efficiency would fall to 72·9 per cent.!

Allowance will have to be made for this and one of the best ways is to reduce the amplification per stage and increase the

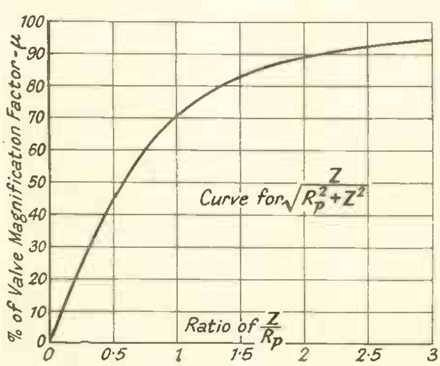


Fig. 9.—Curve showing Percentage Amplification attained, of the Valve Magnification Factor μ for various Ratios of wL to R*p*.

Choke Capacity Coupling. 2

This is illustrated in Fig. 7 and is similar to resistance capacity coupling in that a coupling condenser *c*, and grid resistance R*g* are employed.

The simplest formula for the magnification from a choke coupled stage is,

amplification

$$A = \mu \frac{wLa}{\sqrt{(Rp + Ra)^2 + (wLa)^2}} \quad . \quad . \quad . \quad (1)$$

where the symbols have the following meaning: $w = 2\pi \times$ frequency; L*a* = inductance of choke in henries; R*a* = resistance of choke in ohms; R*p* = valve A.C. resistance and μ = valve magnification factor.

A more complete formula is

$$A = \mu \frac{Za\ (\text{effective})}{\sqrt{(Rp + Ra)^2 + (wLa)^2}} \quad (2)$$

Where Z*a* (effective) is equal to the sum of $wLa + Ra$ with Z_{CR} in parallel,

Z_{CR} being

$$= \frac{1}{\sqrt{Rg^2 + \left(\frac{1}{wC}\right)^2}} \quad . \quad . \quad . \quad (3)$$

It is easily seen that at high audible frequencies Z_{CR} will equal R*g* and Z*a* (effective) will be obtained from

$$\frac{1}{Za\ (\text{eff.})} = \frac{1}{Za} + \frac{1}{Z_{CR}} \quad . \quad . \quad . \quad (4)$$

The proportion of the signal transferred to the grid of V2 may be arrived at from the formula given for the resistance-capacity coupling and the time constant—R × C—may be similarly arrived at. A curve showing the percentage amplification attained, of the valve magnification factor, μ, for various ratios of wL to Rp is given in Fig. 9, and will hold good for ratios of Za (effective) to Rp.

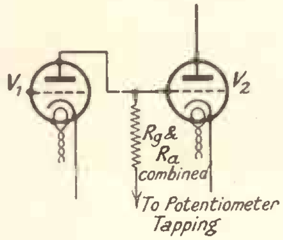


Fig. 10.—DIRECT COUPLING.

A first-class choke should have low self-capacity and resistance whilst possessing a good inductance value. When considering inductances for such a coupling it should be ascertained that the inductance value will not drop unduly with anode current.

Reference to the curve for $\frac{Z}{\sqrt{Rp^2 + Z^2}}$ shows us that 90 per cent. of the valve magnification is obtained when the reactance of the choke, wL, is 2·25 times the valve A.C. resistance. If we consider that wL should be equal to 2·5 times the A.C. resistance of the valve this will leave us a margin for the loss due to the coupling condenser and resistance.

A Typical Case of Choke Coupling

Let us take a typical case. We wish to choke couple an Osram L210 to another valve. Its impedance is given as 12,000 ohms and its amplification factor as 11. From an inspection of the grid volts-anode current curves for this valve we find that at an anode voltage of 125 volts and a negative bias of − 5 volts the valve will pass 3 milliamps. If our choke had a resistance of 1,000 ohms the volts drop due to this would only be 3 volts, so we may neglect this factor. Checking the A.C. resistance at the operating point we find that if we raise the anode voltage 25 volts the anode current increase is 2 milliamps, giving the A.C. resistance as 12,500 ohms. A change of 2 volts on the grid is equal to a change of 25 volts on the anode, so our magnification factor is 12·5.

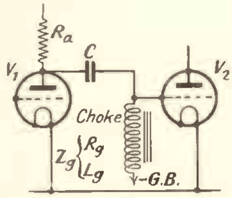


Fig. 11.—GRID-CHOKE COUPLING.

If we take the reactance of our choke as 2·5 times the valve A.C. resistance we shall require 2·5 × 12,500 = 31,250 ohms reactance to give 90 per cent. efficiency. If this efficiency is required at 50 cycles then the inductance of the choke will have to be $\frac{31{,}250}{2 \times \pi \times 50} = \frac{31{,}250}{314}$, which is nearly 100 henries. A shunt resistance of ·5 megohm would barely drop the reactance value 10 per cent. This value will do nicely for a grid resistance. A suitable value for 90 per cent. efficiency at 50 cycles for the coupling condenser would be ·013 mfd. Now ·013 mfd. and ·5 megohm resistance give a time constant of ·0065, and we could try the effect of a condenser which would give a time constant of ·01.

If "blocking" does occur we can always lower the condenser value. So we use a condenser value ·02 mfd., and find, *viâ* Formula 5 of R.C. coupling, that we shall obtain an efficiency at 50 cycles of 96 per cent., which is very good. The amplification will be 90 per cent. of 12·5, which is 11·25. At 50 cycles this will be 97 per cent. of 11·25, which is nearly 11, —a very good figure.

Direct Coupling 3

This form of coupling, where the grid of V2 is directly connected to the anode of V1, is popular in America in receivers and amplifiers built on what is known as the Loftin-White principle. In the case of resistance coupling, given in Fig. 10, the anode resistance and grid resistance are one and the same and calculation is thereby greatly simplified, the amplification in this case being equal to $A = \mu \frac{R}{R + Rp}$, with no corrections due to coupling condensers and leaks. It will be noticed that the valve filaments or rather cathodes are not common, and it is by virtue of the relative positions they are connected to on the H.T. potential divider that valve V2 receives its negative grid bias voltage.

Suitable values for this coupling resistance are from 0·25 to 0·5 megohm with a 224 tube, or, rather, in our own language, a type 224 valve.

This type of coupling has the disadvantage that it cannot be fitted to any type of receiver, but only to the receiver which is built on the Loftin-White principle and is mains operated.

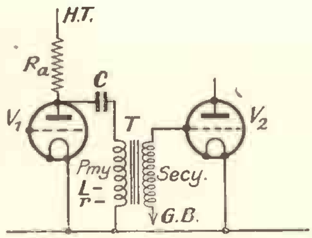


Fig. 12.—PARALLEL FEED COUPLING.

Where L = transformer pmy. inductance

C = the value of coupling condenser.

or $C = 2L\left(\frac{B}{A}\right)^2$

Where $B = 1 + \frac{Ra}{R}$

and $A = Ra + Br$.

As a general rule an anode resistance of 30,000 ohms is used with valves of A.C. resistances up to 14,000, from 7,000 ohms with valves over 14,000 ohms A.C. resistance an anode resistance of 50,000 ohms is used.

Keeping the other factors constant and varying in turn one factor we obtain for :—

Lowered valve A.C. resistance, an increase at the lower frequencies.

Increased inductance, an increase at the lower frequencies.

Decreasing capacity, produces a slight amplification, an increase at the lower frequencies.

Further decrease produces a hump, and still further capacity variation may lead to a series resonant circuit, a thing which is to be avoided.

A few examples are given :—

Valve A.C. res. 5,000 *w* .	Ra	Capacity 3·6 mfd.
Anode, res., 30,000 *w* .	R	
Primy. trans. res., 1,000 *w*	*r*	
Primy. trans. inductance 45 henries . . .	L	

Varying the valve A.C. res. to 10,000 ohms, we should require the capacity to be 1·2 mfd. approx. Considerable latitude may be allowed on this value to the extent of 25 to 50 per cent. The possible variation in the curve being about 20 per cent. for these values at the lower frequencies.

Providing that the coupling condenser and anode resistance are separate from the transformer, an extra step-up may be obtained by connecting the primary and secondary in series (see Fig. 13).

If we take terminal G of

Coupling by Means of Grid-choke 4

This form of coupling is very useful for maintaining the amplification at the lower frequencies and, providing the choke has not too much self-capacity, will amplify the higher frequencies equally well.

It may in fact be considered as a form of parallel feed where the choke is a one-to-one auto-transformer. The formulæ given for parallel feed will apply equally well in the case of grid-choke.

The Parallel Feed Coupling 5

Many excellent commercial units embodying the necessary resistance, condenser and transformer for use with this type of coupling are now available. The advantages of this type of coupling are that (1) the bass response is improved, even when using a small transformer; (2) the inductance of the small transformer is at its highest due to the absence of polarising D.C. current.

How to Calculate the necessary Value

For those who may wish to calculate the values necessary for use with their own transformer the following formulæ are given :—

$$C = 2L\left(\frac{1 + \frac{Ra}{R}}{Ra + r + \frac{Ra}{R}r}\right)^2$$

Where R = coupling resistance.

Ra = valve A.C. resistance.

r = transformer pmy. res.

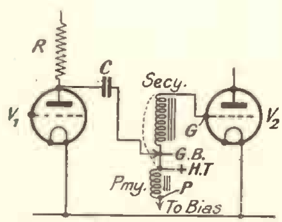


Fig. 13.—HOW EXTRA STEP-UP MAY BE OBTAINED BY CONNECTING THE PRIMARY AND SECONDARY IN SERIES.

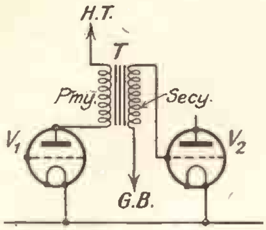


Fig. 14.—TRANSFORMER COUPLING.

secondary to grid and terminals G.B. — to H.T. + and condenser C taking terminal P to neg. bias we obtain an extra one to our step-up ratio. If it previously was 1 to 3, it now will be 1 to 4. If with this arrangement we reverse H.T. + and P, joining P to G.B. — we obtain a decrease in ratio of 1.

If we connect the primary in place of the secondary we obtain a decrease, and if, with the following connections G to grid, H.T. + and G.B. — together, and P to negative bias, we connect capacity C to grid we obtain a 1 to 1 ratio, the coupling now being resistance-capacity and grid choke.

The amplification when using parallel feed is given by the formula :—[1]

$$\mu\sigma \frac{wL}{\sqrt{A^2 + B^2\left(wL - \frac{1}{wC}\right)^2}}$$

where in addition to the previous figures μ = amplification factor of valve, σ = voltage ratio of transformer, and $w = 2\pi f$.

The general amplification using this form of coupling is less than with the standard transformer coupling, the efficiency of this form being about 80 per cent. of the transformer coupling. This type of coupling has the advantage that it is capable of covering a wider frequency range than the standard transformer coupling.

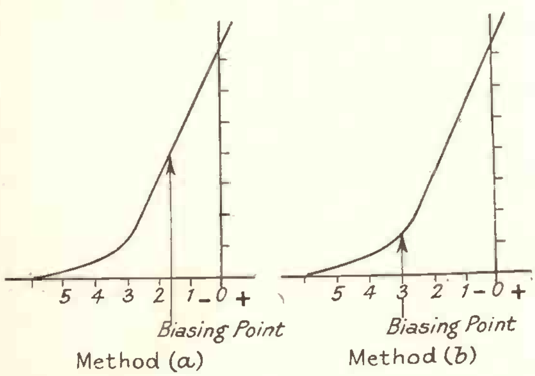


Fig. 16.—TWO WAYS OF UTILISING THE PUSH-PULL CIRCUIT.

(a) Shows the valves biassed to the middle of the straight portion of their characteristic curve: (b) the valves biassed to the middle point of the curved portion at the bottom of the characteristic curve.

Transformer Coupling 6

This type of coupling, shown in Fig. 14, is so well known that it needs little explanation. In choosing a transformer for coupling purposes attention should be paid towards ascertaining if the primary will safely carry the contemplated anode current and maintain an appropriate inductance at that current.

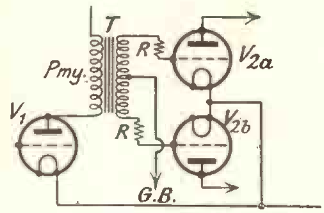


Fig. 15.—PUSH-PULL AMPLIFICATION.

As a very rough approximation we can regard the primary in the nature of a choke and check the per cent. magnification for different values of the ratio of wL or $2\pi fL$ to Rp where L is the primary inductance and Rp the valve A.C. resistance.

Thus $wL = Rp$	.	70 per cent. of μ.
$wL = 1{\cdot}5 \times Rp$	83	,,
$wL = 2{\cdot}5 \times Rp$	90	,,

This method is undoubtedly not the best, but it will serve as a guide when the amplification curve is unobtainable.

For example, one would hardly use a 30-henry transformer—wL value at 50 cycles, 9,420 ohms—with a valve of 10,000 ohms A.C. resistance and expect to obtain really good bass reproduction.

In practice one seldom obtains an amplification equal to the magnification factor of the valve multiplied by the transformer ratio, and it is advisable for the purposes of rough estimation to allow a loss of from 5 to 10 per cent. of this value. Thus a valve with a magnification factor of 10 used with a 3 to 1 transformer may be reasonably expected to give an overall magnification of

27, provided the transformer is a good one.

Push-pull Amplification 7

The circuit is shown in Fig. 15. There are two ways of utilising this circuit. One, Fig. 16 (*a*), where the valves are biassed to the middle of the straight portion of their characteristic curve, and the other, (*b*), where the valves are biassed to the middle point of the curved portion at the bottom of the characteristic curve. In method (*a*), except for the zero points of a cycle, both valves are operating at any given instant. In method (*b*) one valve deals with one half cycle and one valve with the other half cycle. Obviously in method (*b*) the bias will be greater than in method (*a*), so we may consider method (*a*) to be the more sensitive of the two, as less grid swing is required for a given output than with method (*b*).

In so far as the amplification is concerned, we may consider this with respect to either V_2a or V_2b exactly as if we were dealing with a stage of transformer coupling in the normal way.

Use a Stopping Resistance

It is generally wise to connect a stopping resistance R in series with the grid of each valve to prevent parasitic oscillations which sometimes occur when this form of coupling is employed. Resistances of small size of from 20,000 ohms to 50,000 ohms value are quite suitable for this purpose.

It will be appreciated that the intervalve couplings referred to may be successfully employed with a detector stage, but it was considered that it were best to deal with these first as used purely in amplifying stages and to subsequently comment upon them when coming to the detector stage.

THE MILLER EFFECT

In considering the intervalve coupling devices used in low-frequency amplifying stages it was decided to ignore what is known as the "Miller effect" as tending towards complications. In practice, however, this effect is always with us whether we ignore it or not.

Without delving into the matter it will be worth while to give a brief explanation of what constitutes the "Miller effect."

If we take an amplifying valve and, whilst varying the load in its anode circuit, we measure the input impedance of the valve, we shall find that the input impedance will vary with the load in the anode circuit. This was discovered by Mr. J. M. Miller and has since been called the "Miller effect."[2]

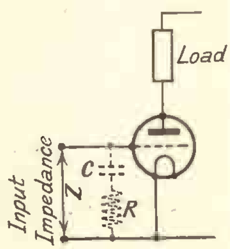


Fig. 17.—THE MILLER EFFECT.

It has been found that the input impedance may be represented as being equal to a condenser C in series with a resistance R across the valve input.

There are two ways in which the input impedance may vary—one where the valve runs into grid current and the other due to the "Miller effect." In making this statement we are neglecting the losses in the valve base, valve-holder, etc. It has been found that the input impedance may be represented as being equal to a condenser C in series with a resistance R across the valve input (Fig. 17).

A Typical Case of Miller Effect

In Fig. 18 we have shown the internal valve capacities C1, C2 and C3. Now when the valve is working the effect will be similar to that shown in Fig. 17, where we have a condenser C in series with a resistance R connected across grid and filament. The value of this apparent condenser C1 will be equal to $(\eta + 1)C3 + C2$, where η is the actual magnification occurring and not μ—the magnification factor of the valve.[3] In the case of a resistance R*a* in the anode circuit η will be equal to $\frac{\mu Ra}{p + Ra}$ where p is the valve A.C. resistance. In such a case the value of R will be small compared with the impedance of C at audio-frequencies and the effect of R may be neglected. The value of the reistance R will vary with the load and it may attain a positive or negative value and due

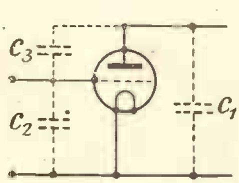


Fig. 18.—SHOWING THE INTERNAL VALVE CAPACITIES C1, C2 AND C3.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8-11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SERVICING H.M.V. 501 RECEIVER

USING VARIABLE-MU VALVES

WIRELESS SOUNDER

1/-

Part 20

IN ABOUT 24 WEEKLY PARTS

PART 20.

to the effective condenser C it will be observed that the input impedance will vary with the frequency.

If we assume a valve where the internal capacities C1, C2 and C3 are each equal to 5$\mu\mu$ fds. and the amplification as being 20 = η, then our value of C will be (20 + 1)5 + 5 = 105 + 5 = 110$\mu\mu$ fds., which is equal to ·00011 mfds. If the value of R was negligible, then the input impedance due to C alone at 10,000 cycles would be approx. 150,000 ohms and at 5,000 cycles 300,000 ohms. All of which goes to show that one cannot afford to neglect entirely this effect, particularly if quality is being sought after.

Miller Effect observed in all Stages

This "Miller effect" may be observed in all stages—H.F., Det. and L.F.—and, for a given state of things, increases with the magnification. Therefore it is unwise to try to obtain too great a percentage of magnification if quality is to be maintained.

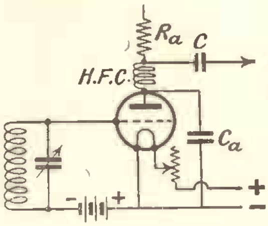


Fig. 19.—Anode Bend Rectification.

In general, the average input impedance of an amplifying valve may be estimated as being from ·5 to 2 megohms, and a rough estimate of 1 megohm will meet the average case.

This will not apply to the detector stage, which will have to be considered on its own merits. The input impedance of a detector stage may vary from ·5 megohm to 30,000 ohms or even less!

What the Miller Effect Does

The Miller effect causes an apparent capacity to be fed back to the input with consequential effects on the tuning. Increasing the anode by-pass condenser will reduce this effect, but unfortunately, when the condenser value has been raised sufficiently to minimise the effect, it has attained such a value that it will by-pass the audio-frequencies, consequently a compromise has to be effected. Therefore the value of the by-pass condenser, C*a* in the diagrams, will have to be adjusted for the best results by experiment in actual practice unless, of course, data is available for the particular conditions existing.

Neutralisation may be effected in certain cases but tends towards expense and complication and, as a general rule, is omitted.

THE DETECTOR STAGE

We now come to consider the detector stage, which is the link between the high-frequency section of the receiver and the low-frequency section or output stage.

Neglecting the use of crystal detectors we will deal with the present-day practice of valve rectification.

A first consideration will show that valve rectification may be subdivided into six main types :—

1. Anode bend rectification.
2. Grid rectification.
3. Cumulative grid or leaky grid rectification.
4. Power grid rectification.
5. Diode rectification.
6. Bi-grid rectification (full wave).

The detector stage occupies a very important part in the design of receivers by virtue of the fact that it is the link between the H.F. and L.F. portions. Apart from the rectifying or detecting properties of this stage it should be remembered that, if distortion occurs here, such distortion will be amplified by the succeeding stages, no matter how perfect they may be. Further, depending upon the detector used, a load will be thrown on to the H.F. section with possibly disastrous effects upon its selectivity and consequential loss of amplification.

It may be as well to remember that no perfect detector or rectifier exists and that, according to requirements, each individual type will have to be considered on its own merits.

Further, no standard formulæ exists for the complete calculation of the detector stage, and, unless one works from data obtainable from the manufacturers and published at times in various periodicals, one will have to conduct one's own experiments in this direction and work from the data thus obtained.

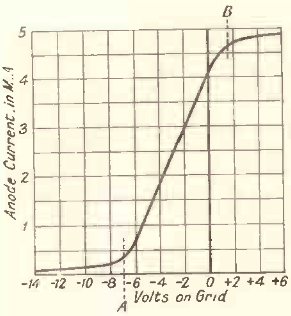


Fig. 20.—Correct Operating Point for Anode Bend Rectifier.

This is at the bend of the anode current - grid volts curve.

In consequence of this the various types of detector are described, together with their advantages and disadvantages and general operating data. This will suffice for the average cases and special cases will require measurements made under working conditions. In general, the use of a Moullin valve voltmeter is strongly recommended as a check on the output voltage from the detector stage.

THE ANODE BEND RECTIFIER

This type of rectifier has enjoyed wide popularity. It possesses several advantages, amongst which are the following :—

Low, steady H.T. consumption.

Capability of handling large inputs.

Imposes little load on the tuned circuit due to being biassed negatively, and by virtue of this selectivity is enhanced.

More free from mains hum than leaky grid rectification.

On the other hand, it possesses several inherent disadvantages.

Whilst it will handle a reasonably large input with ease it is very insensitive to weak signals.

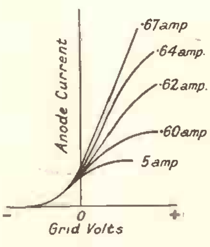


Fig. 21.—Showing Flattening of Valve Curve due to Decrease of Filament Current.

Reaction is not too easily obtained with this type of detector.

Owing to the necessity of having to use steep slope—high magnification valves—practically the only form of coupling suitable to follow this type of rectifier is resistance capacity coupling. This is necessary because of the high internal A.C. resistance of the types of valves mentioned. If a low resistance valve is used with large inputs, transformer coupling may be employed. The primary should have an inductance of 100 henries at least.

Method of Operation and Adjustment

The correct operating point for this type of rectifier is at the bend of the anode current-grid volts characteristic. This will correspond to point A in Fig. 20. This point may be reached either by biassing the valve accordingly, leaving the anode voltage fixed, or by fixing the bias voltage and varying the anode voltage until the correct point is reached. Increasing the anode voltage of a valve has the effect of moving the anode current-grid volts curve bodily to the left, whilst decreasing the anode voltage produces the opposite effect. Rectification may be obtained by working on the upper part of the curve—as at B (Fig. 20). This point may be reached by varying anode volts or by using a potentiometer to vary the grid voltage. The curve may be suitably flattened by decreasing the filament current. This method is not the method meant when anode bend rectification is referred to, so we will call this anode rectification. Owing to the fact that it imposes a greater load on the preceding tuned circuit together with the fact that it utilises more H.T. current and is less easy to adjust, this method is little used at present.

Practical Notes on Operation of Anode Bend Detector

With this type of detector it is essential that the by-pass condenser, from anode to – L.T. or earth, be included. Omission of this will result in little, if any, rectification due to Miller effect. If this condenser is made large there will be a loss of audio-frequencies. A suitable value is from ·0001 to ·0002 mfd. for good quality reception and up to ·0005 where quality is not so important a factor. A very

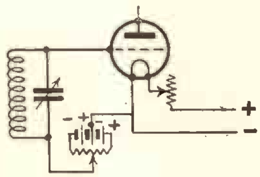


Fig. 22.—Grid Rectification.

suitable value of anode resistance is 100,000 ohms, and it is inadvisable to attempt the use of valves having a higher A.C. resistance than 20,000 to 30,000 ohms, as the actual A.C. resistance, under working conditions, will be much higher than the maker's rating. For good quality results with anode bend it may be necessary to lower the anode resistance value to reduce high note loss due to the anode bypass condenser. This will lead to poor amplification, but one cannot have it both ways. If a transformer is used it should have a primary inductance of not less than 100 henries.

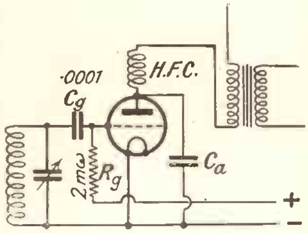


Fig. 23.—Cumulative Grid or Leaky Grid Rectification.

Distortion on Weak Signals

An input signal voltage of over ·5 volt is necessary when using an anode bend detector valve, as with lower signal voltages than this its sensitivity and efficiency drop, and distortion will occur with weak signals.

If the H.F. choke in the anode circuit is omitted, H.F. currents will be transmitted through to the low-frequency stages, necessitating the use of grid stopper resistances between the grid of the amplifying valve and the transformer secondary or junction of grid condenser and leak.

Why a High Anode Voltage is advisable

It is advisable to maintain a fairly high anode voltage with this type of detector in order to avoid distortion in the course of L.F. amplification, which occurs in the valves due to the valve grid volts — anode-current curve being more curved at the low voltages than at high.

Pentodes and screened-grid valves can be utilised as anode bend detectors, and whilst the pentode will give greater output than the triode or ordinary valve, it is not used much on account of its consumption and cost.

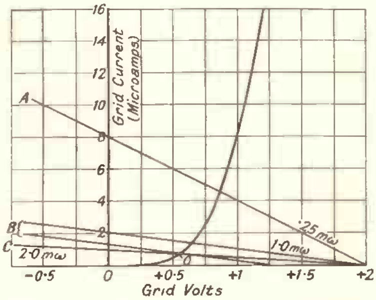


Fig. 24.—Method of Determining Operating Point.

The screened-grid valve is better employed as a leaky grid detector than as an anode bend detector.

GRID RECTIFICATION

In this method of rectification illustrated in Fig. 22 the grid was biassed to the bend in the grid-volts-grid current characteristic by means of the potentiometer.

This method was used extensively with valves of the "soft" variety and gave way to cumulative-grid rectification. It was a much more sensitive method than anode-bend but had the disadvantage of imposing a load, in excess of that imposed by leaky grid method, on the tuned circuit.

Cumulative-Grid Rectification

This may be considered to be one of the most popular, if not the most popular, methods of rectification in use mainly on account of its sensitivity. The typical circuit is illustrated in Fig. 23. There are many advantages obtainable with leaky-grid rectification.

For inputs under ·5 volt, or, say, ·8 volt, it is much more sensitive than anode bend —the output at low inputs reaching six times that obtainable with anode bend.

Transformer, choke, resistance or parallel feed couplings may be employed with this form of detector, and with the advent of parallel feed it is not necessary to consider the effect of anode current on transformers connected in the anode circuit.

It has a few disadvantages—chief amongst them being the fact that it imposes a heavier load on the tuned circuit than anode bend. It will not handle heavy inputs, in fact, it may be limited to approximately 1 volt input.

Once the output from this type of detector reaches a certain value, depending on the valve employed, further increase in input signal voltage results in no increase in output.

Practical Considerations

The value of grid condenser and leak is not really critical—values of condenser ranging from ·0001 mfd. to ·0003 mfd. with leaks of from ·5 to 3 megohms being general. In practice it will be found that the following effects occur.

Capacity of Grid Condenser that is most Suitable

If the grid condenser is increased reaction will be easier to obtain and there will be at the same time a noticeable reduction

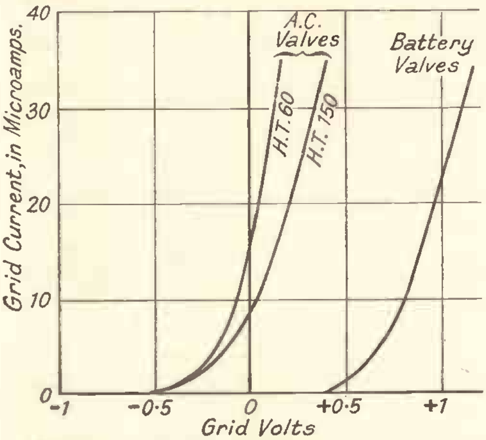


Fig. 25.—Grid Current Curves for A.C. and Battery Valves.

of high notes after a value of ·0002 mfd. has been reached.

On the other hand, if the capacity is decreased to a small value, say ·000015 mfd., the signal strength will be decreased. Actually the smallest value of capacity which does not entail loss in signal strength is the best value to use, and in general practice a value of ·0001 mfd. is chosen for use on medium and long wavebands.

Value of Grid Leak

The grid leak value will depend upon the condenser value, and it will be found that, with too large a leak, high note loss will occur whilst with too low a value the output from the detector will decrease and the tuning will be flattened, due to additional load across the tuned circuit. Therefore, in practice, a value of approx. 2 megohms is used as being the best compromise.

Now we can take the RC value of these two, ·0001 and 2 megohms, and the result is ·0002 = RC. So, if we used a ·00005 condenser we should have the same time constant with a 4-megohm leak as we did with the ·0001 mfd. condenser and 2-megohm leak.

The Operating Point—O

The operating point chosen is on the bend of the grid current-grid volts characteristic, and, in the case of a battery valve, is illustrated in Fig. 24. The load line for 2 megohms is line C. Starting from + 2 volts it cuts the zero line at 1 microampere and its resistance is

$$\frac{2 \text{ volts}}{1 \times 10^{-6} = (1 \text{ microampere})} = 2 \times 10^6 \text{ ohms.}$$

In like manner load lines for any value may be constructed. A is equal to ·25 megohm and B equal to 1 megohm. As described previously in "How to Match Loud Speakers to the Output Stage," parallel load lines have the same resistance and the two B lines are therefore 1 megohm each. It will be observed that one of the megohm lines is well above the operating point. The other one, which practically coincides with the operating point and is parallel to the first B line, shows us, from where it cuts the grid volts line, the voltage to which the end of the leak must be connected so that the valve may be operated about point O for this value of leak. In like manner the voltage value to which the end of the grid leak, of any value, should be connected may be determined. This would call for the use of a potentiometer, and this is a definite necessity in the case of valves of over 2 volts filament rating, and in the case of

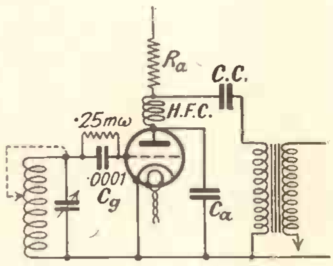


Fig. 26.—Power Grid Rectification.

all valves of battery type when operated as "power grids." In the case of 2 volt valves the leak is usually connected to + L.T. or positive filament. With A.C. valves grid current commences at a negative voltage and the leak is, as a rule, connected to cathode (Fig. 25).

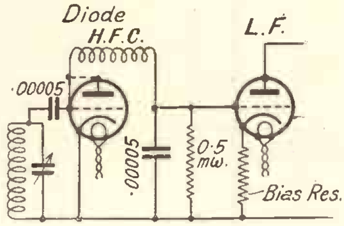


Fig. 27.—Diode Rectification.

With this type of detector it is essential for quality results that anode voltages of a fairly high order be used—such as 150 volts and over.

The Grid Leak Value

In order to keep down high-note loss the grid leak value must be carefully considered. It can be computed from the following formula:

$$R = \frac{1}{2\pi f C},$$

where R is the resistance value in ohms, C is the grid condenser capacity *plus* the total grid filament capacity and f the highest frequency it is considered necessary to retain.

Thus if the grid condenser value is ·0001, the valve filament grid capacity 8$\mu\mu$ fds. and the incidental capacities 12$\mu\mu$ fds. we have for a value of 5,000 cycles

$$R = \frac{1}{6{\cdot}28 \times 5000 \times {\cdot}00012 \times 10^6} = \frac{10^6}{3{\cdot}768} = {\cdot}265 \text{ megohm.}$$

Similarly, if we had decided on a frequency of 10,000 cycles the value of R would have been ·1325 megohm.

The average A.C. power grid detector, transformer coupled, will deliver an output of approx. 40 volts to the power valve grid, and if an A.C./pentode be used as a power grid detector it will, with an input of 5 volts R.M.S., deliver an output of approx. ·5 watt, and may therefore be coupled directly to the loud speaker.

A power grid detector, to function at all well, should not be fed with an input lower than ·5 volt. Below this value it will not function as a "power grid" detector but rather as a "leaky grid" detector having a low value of leak, and the result will not be as distortionless as with genuine "power grid" working.

Recent Developments

The screened grid valve has recently been pressed into service as a leaky grid rectifier, and its use confers two main advantages—(1) that it is more sensitive, and (2) that it imposes less load on the tuned circuit than the ordinary leaky-grid detector. It may be choke-coupled, resistance or parallel-fed transformer, coupled to the succeeding valve, and from a quality point of view this last method is very good.

If reaction is not employed the screened-grid valve will be found to be more sensitive by far than the ordinary triode. The use of reaction with the triode will increase its efficiency to a greater extent than it will with the screened-grid valve.

POWER GRID RECTIFICATION

The circuit of this form of rectification (Fig. 26) is at first sight similar to that of leaky grid. There are, however, inherent differences. One is the value of grid leak and the other is the fact that with leaky grid rectification grid current occurs on both half cycles of input swing, whereas with power grid it occurs on one half cycle only.

This method of rectification has the disadvantage of imposing a heavy load on the tuned circuit.

On the other hand, it will handle large inputs and give less distortion than with the previous methods described, and the load imposed on the tuned circuit may be minimised by connecting the input to the detector to a tapping point on the coil of from half to two-thirds the total number of turns.

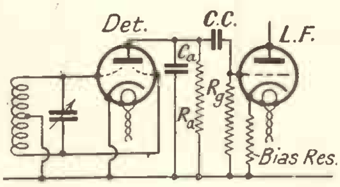


Fig. 28.—Bi-grid Rectification.

DIODE RECTIFICATION

This is probably the most distortionless type of rectifier. A form of diode rectifier is shown in

Fig. 27. This was developed by Mr. Kirke, of the B.B.C.

It will be observed that a separate valve is used for the L.F. magnification which normally would have been accomplished in the one valve in the preceding methods. Because of this expense and complication the method is little used. With this arrangement, however, the possibility of L.F. distortion with rectification is minimised, and it possesses the further advantage of no "feed back" due to Miller effect. Its load on the tuned circuit, therefore, is less than that of the leaky grid rectifier.

In setting up this type of rectifier it is essential that the H.F. choke has a low self capacity and that the L.F. valve has no grid current. This can be achieved by biassing. The blocking condenser in the grid circuit is kept low in value, its value being approx. that shown in Fig. 27.

BI-GRID RECTIFICATION

This method has been recently developed in America more for the purpose of obtaining automatic volume control than for the sake of rectification. As it is a new form of rectifier, it comes within the scope of this article, and a circuit illustrating same is given in Fig. 28. I have given it the name of "Bi-grid," as I feel that this will best define it. Actually it is a form of full wave Diode rectifier, and, as far as a rectifier is concerned, may be treated as a Diode. It is exemplified in the valve known as the "Wunderlich Valve," and as little data regarding this valve is at present available, little can be said about its performance as a rectifier.

H.F. COUPLINGS

In Figs. 29, 30, 32–35, we have illustrations of the various forms of coupling used to couple one high-frequency stage to another one or to the detector stage.

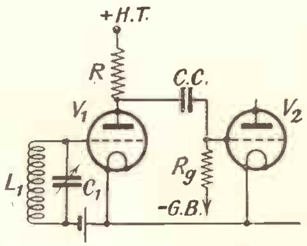


Fig. 29.—Resistance Capacity Coupling.

The various forms of coupling used for such purpose are as follows:—

(1) Resistance capacity coupling.
(2) Choke coupling.
(3) Tuned anode.
(4) Tuned grid or parallel feed.
(5) Transformer.
(6) Band-pass.

Re-arranging these *in order of cost* we have the following order: 1, 2, 3, 5, 4, 6, No. 1 being considered the cheapest.

In order of amplification: 5, 4, 3, according to design; then follows 6, 2 and 1.

In order of selectivity: 6, 5, 4, 3, 2, 1.

Referring to Figs. 32 and 33, where the anode or H.T. is shown taken to tappings on the coils, it will be obvious that this arrangement constitutes a form of auto-transformer, but, as it does not affect the type of coupling used, no separate type name has been given to cases where the coils are tapped.

Considering the various diagrams it will also be noticed that no de-coupling arrangements have been shown. These have been purposely left out to avoid complication when considering the various types of coupling, and will be dealt with later.

1. RESISTANCE CAPACITY COUPLING

This form of coupling may be treated in much the same way for high-frequency coupling as it was for low-frequency coupling. Owing to the high value of the internal A.C. resistance of screened-grid valves, resistance coupling is rarely employed with such valves and is more commonly found with the ordinary triode valve. Owing to its compactness it was, together with choke coupling, a

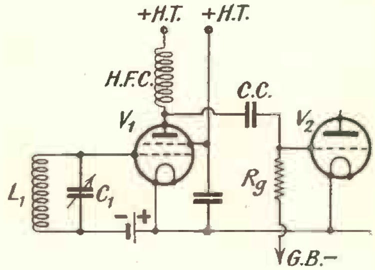


Fig. 30.—Choke Coupling.

favourite method for use with portable receivers where space is an all-important item.

A Few Practical Hints regarding H.F. Amplification.

When choosing valves for H.F. couplings it is worth while to take note of their internal capacities, together with the magnification factor value, as, apart from the nature of the anode load, these will largely determine the amount of feed back due to Miller effect.

The valve holders will well repay attention. These should be checked for self capacity and leakage, and it is as well to note that a leakage value of, say, x, measured with a steady D.C., may change to a value of $10x$ when measured with the same potential value but with high-frequency. A suitable method of testing valve holders is to shunt them across a tuned circuit and, after re-tuning to allow for self capacity, observe the change in dynamic resistance value of the tuned circuit. Grid-filament, grid-anode, and anode-filament terminals should be connected across the tuned circuit in turn. The results, in some cases, will be found to be very instructive.

The formulæ for use with resistance capacity coupling are much the same for H.F. work as for L.F., the difference in frequency being taken into account.

Values for Condensers and Resistances

Suitable values of coupling condenser, C.C., and grid resistance Rg are ·0003 mfd. and 2 megohms, or ·0005 mfd. and 1 megohm. When considering the frequency of the medium waveband and long waveband one may be tempted to use a different value of condenser and leak for long waves, but, as a rule, in general practice, the gain being only a few per cent., it is not worth it.

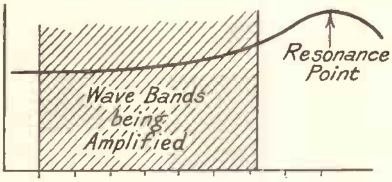


Fig. 31.—THE RESONANCE POINT.

This should be well outside the wavebands which are to be amplified.

2. CHOKE COUPLING

This form of coupling is sometimes referred to as impedance coupling or aperiodic coupling.

It should be aperiodic in nature if not in name, which is to say that the choke employed should *not* resonate on any of the wavelengths which are being amplified—its resonance point should be well outside the wavebands which are to be amplified (Fig. 31).

Instability in H.F. stages employing choke coupling may frequently be due to the choke's resonant point being in the wrong place and on some occasions to coupling between the H.F. choke and other parts of the receiver. Further, a good H.F. choke should have a low self capacity, a low D.C. resistance and a small external field, whilst possessing a good inductance value.

Where resistance coupling would cause a considerable voltage drop, particularly in the case of screened-grid valves which would require anode resistances of high value, choke coupling will be found to be most suitable. This would provide a cheap single stage of H.F. amplification which requires no tuning control. Suitable values for C.C. and Rg of Fig. 30 would be from ·0002 to ·0005 mfd. and from 1 to 3 megohms respectively.

Formula

The formula for this stage is practically identical with that for choke coupled L.F. stages, but in view of the high value of the frequencies which we are amplifying rather more attention will have to be paid to the effect of stray capacities than was the case with the L.F. circuit. The average value of stray capacity across anode and earth, thus virtually across the choke, may be of the order of from 10 to 25 micro micro-farads.

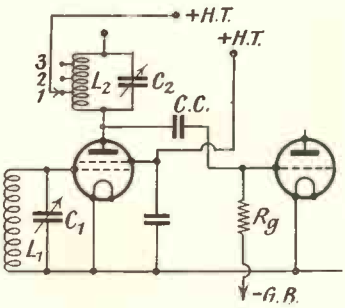


Fig. 32.—TUNED ANODE COUPLING.

The amplification obtainable is equal to:

$$A = \mu \frac{\sqrt{r^2 + \omega L^2}}{\sqrt{(Rp + r)^2 + \omega L^2}}$$

where L = inductance of choke in henries.
r = resistance of choke in ohms.
Rp = valve A.C. resistance.

The above holds good providing the effect of the coupling condenser, grid leak and stray capacities are negligible.

The effect of coupling condenser and leak may be computed from the formula given in the L.F. section, and the impedance of the choke with the stray capacity in shunt may be calculated separately, if desired, but in general practice this is hardly worth the trouble.

Two Choke Coupled Stages

If two choke coupled stages are used the amplification will increase enormously at the longer wavelengths due to approaching resonance, and two such stages are not recommended for use on both medium and broadcast wavebands.

Due to internal feed back in the valve the choke stage imposes a load on the tuned circuit to which it is connected. As reaction is generally used with this stage, this will to an extent compensate for this, but if no reaction is to be used it may be preferable to employ another form of coupling such as tuned anode or use a screened-grid valve as the load imposed by choke coupling following a screened-grid valve is very much smaller than that imposed if an ordinary three-electrode valve is used.

3. TUNED ANODE COUPLING

The circuit is illustrated in Fig. 32 and operates by virtue of the dynamic resistance of the tuned circuit L_2C_2 at resonance. This dynamic resistance R_1 is equal in value to $\frac{L}{Cr}$, where r is the H.F. resistance of the coil; L its inductance in henries and C the capacity tuning it to resonance. Due to the value of r changing with frequency the value of R will change accordingly, and, as a general rule, the value of R is lower at 550 metres than at 300 metres wavelength.

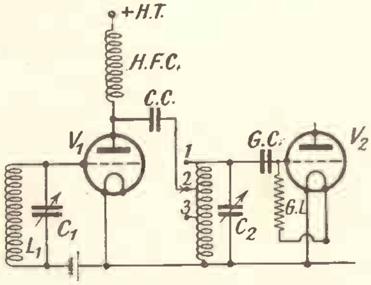


Fig. 33.—TUNED GRID COUPLING.

Effect of Stray Capacities

The effect of stray capacities which may effectively be in shunt with the tuning capacity C is to decrease its setting slightly to C_1 so that the shunt capacities $C_s + C_1$ together equal the actual capacity C. These may therefore be embodied in C and neglected otherwise.

If the coupling condenser impedance is negligible we may consider the leak Rg as a shunt across the tuned circuit. The dynamic value will be altered thereby to R_1, which will be equal to $R_1 = \frac{RRg}{R + Rg}$ ohms. Having ascertained this value we may insert it in the standard resistance coupling formula, and from this we will obtain the magnification of our valve and tuned circuit. Thus amplification $= \mu \frac{R_1}{Rp + R_1}$, where Rp = valve A.C. resistance and μ its amplification factor.

Why great Amplification is not obtained

At first sight it would appear that providing we make R_1 large enough and use a valve of high μ we should obtain great amplification, but such is not the case, as there is a limit to the value of R_1 which may be used before self oscillation takes place.

Formula for Threshold Instability

Mathematicians give a formula for threshold instability as follows:—[1]

$$\frac{Co\omega G}{\frac{1}{R}\left(\frac{1}{R} + \frac{1}{Ro}\right)} = 2$$

Co—Valve anode-grid capacity in farads,
G—Valve mutual conductance in MA/V,
Ro—Valve A.C. resistance under operating conditions,
R—Dynamic resistance in anode circuit of valve.

from which the value of R may be obtained. This value will be our value of R_1 for optimum conditions, and is seldom attained in practice as it generally gives a value of R_1 which, considering the average commercial coils, is rarely attained unless Litz wire is used.

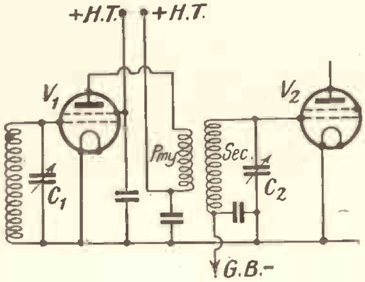


Fig. 34.—TRANSFORMER COUPLING.

transformer. This will tend to reduce amplification but improve selectivity and, except for the fact that it is auto-transformer, may be considered as a transformer with the coupling resistance shunted across the secondary—the primary and secondary being auto-coupled.

An Example

If we assume a solid wire coil with a dynamic resistance of 100,000 ohms, when used at 250 metres, a screened-grid valve of 500,000 ohms A.C. resistance and a magnification factor of 500, what value amplification might we expect ?

$$A = \mu \frac{R}{Rp + R} = 500 \frac{100{,}000}{500{,}000 + 100{,}000}$$
$$= 500 \times \cdot 16 = 80 \text{ magnification.}$$

If we neglect the coupling condenser and assume a coupling resistance of 1 megohm, then our value of R which was 10^5 ohms will now be

$$\frac{RRg}{R + Rg} = \frac{1 \times \cdot 1}{1 + \cdot 1} = \frac{\cdot 1}{1 \cdot 1}$$
$$= \cdot 090 \text{ megohm} = 90{,}900 \text{ ohms.}$$

This will be the effective dynamic resistance, R_1, in the anode circuit, and so our amplification will be reduced to

$$500 \frac{\cdot 09}{\cdot 5 + 09} = 75 \cdot$$

So that we sustain a loss of about 7·5 per cent. due to the effect of the grid leak.

Incidentally, the value of R_1 for "threshold instability" for a screened-grid value of the type we have just considered is approximately 300,000 ohms.

Practical Considerations

We may obtain instability with our 100,000-ohm dynamic resistance in actual practice due to poor screening, capacity or inductance effects in the wiring in the circuit, and it is well to see to these first before attempting the use of coils with higher dynamic resistances.

It will be noted that in Fig. 32 the coil is shown tapped, and this is done to obtain a step-up effect—in effect an auto-

4. THE TUNED GRID COUPLING

In the tuned anode coupling the H.T. supply to the valve is taken through the coil and, by virtue of this, the tuning condenser, C, is at high potential to earth. This could be obviated by connecting its fixed vanes to a blocking condenser and the other side of the blocking condenser to the coil—the moving vanes being earthed. In the tuned grid method this difficulty does not arise as the coil and condenser are either earthed, or practically so, through the bias.

It will be observed that we have a similar circuit to our tuned anode but with a choke shunting the tuned circuit instead of the grid resistance—assuming the effect of the coupling condenser to be negligible.

Formula for determining Magnification of Tuned Circuit

If we consider the same tuned circuit as that used in the tuned anode case having a dynamic resistance of 100,000 ohms and employing the same valve, we can arrive at the magnification of our tuned circuit in the following manner :—[2]

The choke we intend using possesses, shall we say, an impedance of 12,000 ohms at, say, 250 metres, and has a resistance of 400 ohms. This can be replaced by an equivalent resistance of

$$\frac{\text{Choke impedance}^2}{\text{Choke resistance}} = \frac{12{,}000^2}{400}$$
$$= \cdot 36 \text{ megohm.}$$

Now our coil dynamic resistance will be in parallel with this, which is $\frac{\cdot 36 \times \cdot 1}{\cdot 36 + \cdot 1} = \frac{\cdot 036}{\cdot 46} = \cdot 08$ megohm approx. for R_1. Had the choke been of a higher grade giving an equivalent resistance of ·5 megohm we should have obtained $\frac{\cdot 05}{\cdot 60} =$ ·083 megohm for R_1.

Calculating the Amplification

The amplification may be calculated in the same manner as for tuned anode and for the same valve would be $A = 500 \times \frac{\cdot 083}{\cdot 5 + \cdot 083} = 71$ approximately.

This shows the importance of choosing a good choke and the figures chosen by no means represent a really good choke.

This method of coupling affords great facilities for ganging and switching and is in consequence very popular.

The coil may be tapped as shown in Fig. 33 when the shunting effect of the choke will not be so great and a step-up auto-transformer arrangement similar to that for tuned anode may be used. This arrangement will tend to improve the selectivity.

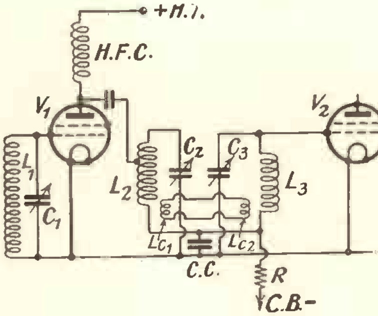


Fig. 35.—Band-pass Coupling.

5. TRANSFORMER COUPLING

This method of coupling is also very popular, and if a neutralised transformer be constructed (Fig. 34) is practically the only satisfactory method for coupling triode valves which have a threshold stability value considerably less than that of screened-grid valves.

The Correct Ratio

If we know the value of the dynamic resistance of the secondary—R and the value of the valve A.C. resistance R_p, then the optimum ratio is

$$N = \sqrt{\frac{R}{R_p}} \quad (1)$$

If the dynamic resistance of the pmy. $R_1 = R_p$ then the amplification due to this will be $\frac{1}{2}\mu\sqrt{\frac{R}{R_o}}$ which equals

$$\tfrac{1}{2}\mu N \quad . \quad . \quad (2)$$

Thus if the secondary has an R value of 400,000 ohms. then if the valve A.C. resistance is 100,000 ohms the correct ratio will be $\sqrt{\frac{4 \times 10^5}{1 \times 10^5}} = 2$ to 1 step-up. This formula applies to L.F. transformer stages. If we assume the valve to have a magnification factor of 200 then the amplification would be $\frac{1}{2}\, 200 \times 2 = 200$, assuming the primary dynamic resistance of the transformer to equal the valve A.C. resistance.

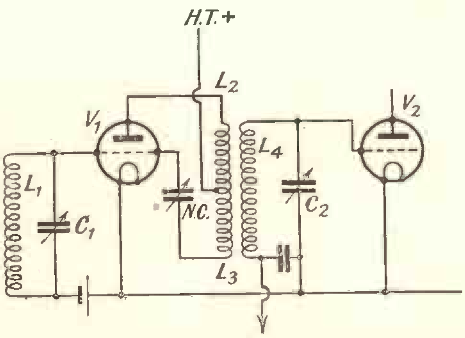


Fig. 36.—Neutralised H.F. Transformer.

Ratios generally Used

If now the optimum turns ratio N be worked out for a number of screened-grid valves it will be found that it will give as a general rule a number of step-down values of ratio and, in some cases, a number of 1 to 1 ratios. It is not practicable to construct transformers having such ratios with secondaries of appropriate dynamic resistances and, even if a 1 to 1 transformer is used, it will be found that selectivity will be poor. Therefore in practice step-up ratio transformers with ratios of from 1 to $1\frac{1}{2}$ and 1 to 3 are employed. This is done to effect a compromise between amplification and selectivity.

6. BAND-PASS COUPLING

This method of intervalve coupling is not widely employed as yet but it affords many advantages as far as selectivity is concerned and a receiver with band-pass input and band-pass intervalve coupling with possibly a good tuned grid stage following should give a degree of selectivity little inferior to some superheterodynes.

Unfortunately there is little in the way of formulæ available for calculating the magnification obtainable from such as intervalve coupling but a good approximation may be made.

We will assume we have a good band-pass filter whose constants are known. Now, if for the moment, we forget that it is a band-pass filter, and, taking the values of one of its tuning coils work out the amplification obtainable, we shall arrive at a certain figure, x. The actual amplification we shall obtain with the band-pass may be estimated as being approximately equal to ·75 x, and we shall not be very far out.[3]

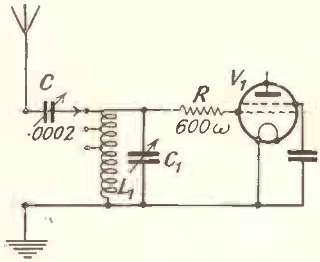


Fig. 37.—Simple Condenser Coupling.

With grid stopper resistance.

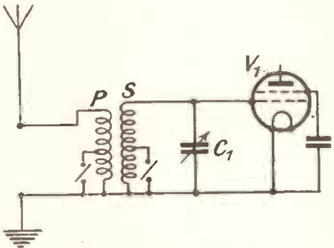


Fig. 38.—Aerial H.F. Transformer Coupling.

A FEW PRACTICAL HINTS

In considering the various couplings and the amplification obtainable therefrom we have neglected the effect of the input impedance of the valve, and the effect of this, except in cases where it is regenerative, will be as if the H.F. resistance of the coil were increased thereby giving a lower value of dynamic resistance.

Input Impedance Values

In cases where the input impedance values are known correction can be made accordingly in estimating the resultant value. In cases where the input impedance is not known it will be necessary to estimate the amount of same by experiment or by measurement and to correct accordingly. In practically all cases some experiment will be necessary.

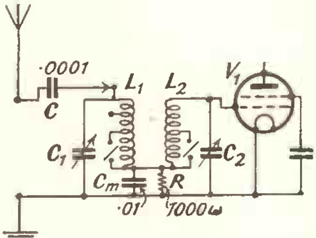


Fig. 39.—Capacity-coupled Band-pass Filter.

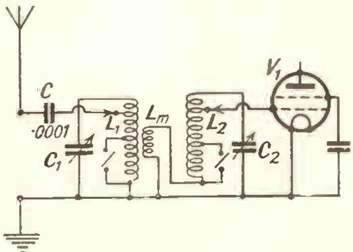


Fig. 40.—Inductively Coupled Band-pass Filter.

Suitable for input to superheterodynes.

Reducing Load Effect

In the case of a tuned circuit coupled to a power grid detector it is almost always essential to "tap" the coil and to connect the grid condenser to the tapping in order to reduce the load effect of the detector upon the tuned circuit.

A Typical Case

If we assume the detector load to be a pure resistance of, say, 25×10^3 ohms and the tuned circuit dynamic resistance to be 10^5 ohms then

$$\sqrt{\frac{\text{Coil dynamic resistance}}{\text{Input resistance}}}$$

should give us an appropriate tapping ratio.

In the case under consideration we have

$$\sqrt{\frac{1}{\dfrac{10^5}{25 \times 10^3}}} = \sqrt{\frac{1}{4}} = \frac{1}{2}$$

so that by tapping the coil half way we should obtain better results than we would by taking the detector to the top of the coil. As a general rule $\frac{1}{2}$ to $\frac{2}{3}$ tapping is suitable in the case of power grid detectors and this is found to be the case in practice.

Unless full particulars are available it will generally be necessary to conduct experiments in order to effect the best compromise for the results required.

Increasing H.F. By-pass Condenser

Increasing the H.F. by-pass condenser will reduce the load on the tuned circuit but will drop the value of high note amplification in the L.F. stage, and while one may arrive at a certain value by experiment and aural results, it should be borne in mind that it is exceedingly difficult to estimate aurally losses in frequencies over 5,000 cycles. In this case calculation is an asset, if not a necessity.

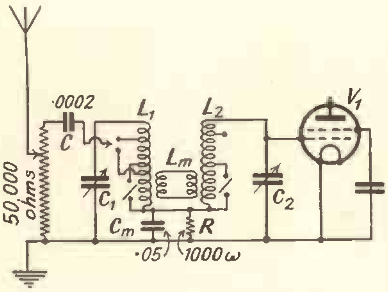


Fig. 41.—Mixed Band-pass Filter.
For constant peak separation.

Whenever it is possible to take measurements it is as well to do so as a check on any calculations made. It will be found in practice that measurements will reveal all sorts of factors which have not been taken into account when making calculations and much valuable and useful information is obtained in this way.

THE INPUT TO THE FIRST VALVE

This may be by means of a band-pass filter, a single tuned circuit, an H.F. choke or resistance according to requirements. An H.F. transformer is another very efficient method of coupling.

These various methods together with aerial coupling arrangements are illustrated in Figs. 37 to 42, which are self-explanatory.

Choice of the method to be adopted will depend upon the required performance from the receiver in the nature of sensitivity, selectivity, quality, simplicity of control and price.

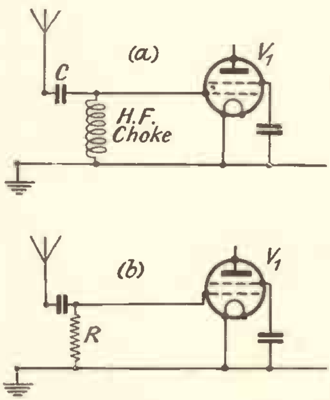


Fig. 42.—Choke and Resistance Coupling.

(*a*) Choke coupling suitable for short wavelengths. (*b*) Resistance coupling suitable for ultra-short waves.

Sensitivity

This will, to an extent, be limited by the other factors which have governed the type of receiver required, but if the maximum sensitivity is required the magnification factor of the coils utilised will be the governing factor, apart from the valves.

The magnification of a coil is equal to $\frac{2\pi f L}{R}$ ... where L is its inductance in henries, f the frequency and R its total effective high-frequency resistance at that frequency.

Coils have been graded in four classes. The first class those with magnifications of 200 and over; second class—150 to 200; third class—100 to 150, and fourth class all under 100. Therefore, if the maximum sensitivity is required, we should use first class coils.

The use of very high magnification coils, other than in a band-pass unit or with correcting circuits following, will lead to a loss of high notes due to side band cutting apart from incidental troubles which may occur in screening the coils and instability due to feed back.

Selectivity

This is an important item nowadays and it depends largely upon the number of tuned circuits employed and the magnification of the coils.

If we take a tuned circuit and measure the voltage at resonance and then, leaving the circuit alone, vary the frequency until the voltage is 1/10th of what it was at resonance we will obtain a figure by dividing the resonant frequency in kilo-cycles by the change in frequency in kilo-cycles. This figure is known as the selectivity number.[4]

For example, if the resonant frequency was 1,000 k.c. and the frequency change to drop the voltage 1/10th was 10 k.c. then the selectivity number would be

$\frac{1,000}{10} = 100$. This number has also been given as equal to $\cdot 2 \times$ the coil magnification factor, M.

It has been found in practice that, as far as selectivity is concerned, it is better to use several stages with poor coils in them than just a couple of stages of good coils.[5]

A later article deals fully with the design of an actual receiver.

Bibliography

[1] F. Aughtie, Ph.D., M.Sc., and W. F. Cope, B.A. *Wireless World*, November 11th, 1929, and *Experimental Wireless*, April, 1931.

[2] See *Bulletin U.S.A. Bureau of Standards*, No. 351.—J. M. MILLER.

[3] Described by N. W. MACLACHLAN, D.Sc., M.I.E.E., in *Wireless World*, January 5th, 1927, p. 21.

[4] MR. KIRKE, of the B.B.C. *Wireless World*, February 3rd and April 20th, 1032.

Tuned Anode Coupling.

[1] W. A. BARCLAY, M.A. "Threshold Instability." *Wireless World*, September 2nd, 1931.

[2] S. O. PEARSON, B.Sc. M.I.E.E. "Tuned Grid Coupling." *Wireless World*, January 21st, 1931.

Transformer Coupling.

[3] "Band Pass Coupling." *Wireless World*, October 30th, 1929.

[4] R. T. BEATTY, M.A., B.E. D.Sc. "Selectivity." *Exp. Wireless*, July, 1930.

[5] S. BUTTERWORTH of N.P.L. "Coils." *Wireless World*, December 8th and 15th, 1926.

EARTH SYSTEMS

ONE of the most satisfactory earth systems is that consisting of a metal pipe or tube about 2 feet long driven well into the ground about a yard from the side of the house. The earth wire from the set should be either soldered or screwed on to the pipe, and should be kept as short as possible. About 12 feet is the maximum length if losses are to be avoided.

An alternative method is to use an old galvanised pail or a biscuit tin, which should be buried several feet deep in the ground. About a dozen holes should be punched in the sides and the tin filled with coke. The ground above should be watered from time to time, unless already very damp. The coke retains the moisture, thus increasing the efficiency of the earth.

When a soldered joint is made to an object which is buried in the ground, the chemicals in the earth may eventually cause the joint to corrode, with the result that the wire may become disconnected. This can be prevented by covering the whole of the joint with pitch which can be obtained from an old H.T. battery.

Earths in Flats

In flats and other places where access cannot easily be obtained to the ground, other methods have to be adopted. A wire connected to a main water pipe will nearly always prove satisfactory. It should be soldered or joined to the pipe with a clip, first making sure that the pipe is quite clean. Gas pipes should not be used as "earths."

Counterpoise Earth

Another form of earth system is that known as a counterpoise earth. This consists of a copper gauze mat or a length of wire which can be placed under the linoleum or carpet, or along a skirting board.

THE WIRELESS SOUNDER

By EDWARD W. HOBBS, A.I.N.A.

THE Echometer, or wireless sounding device, is a recent development of radio—due largely to the work of Langevin, Chilowsky and Florrison—for determining the depth of water beneath a ship. It is extensively used on trawlers when searching for fish, and on big ships as an aid to safety of life at sea and as a help in navigating the ship.

Fig. 1.—THE MARCONI ECHOMETER SOUNDING DEVICE FITTED TO S.S. *Pennyworth*.

The operator can see by looking at the indicator the exact measurement of the depth of water beneath the ship.

Importance of Sounding Device

The practical value of an efficient sounding machine can be judged from the fact that over half of all marine losses are due to running aground or stranding, a loss that can be largely minimised by an apparatus that enables rapid automatic readings of the depth of water.

The Marconi sounding device, which is particularly described here, enables automatic and direct readings of the depth of water under the keel from 2 fathoms (12 feet) to 360 fathoms, that is, 2,160 feet, to be taken nearly once per second.

An operator taking an echometer reading is shown in Fig. 1—all that he has to do is to switch on and note the readings on the indicator.

Description of Apparatus

The sounding device made by the Marconi Sounding Device Company consists of two main parts—the under-water projector and the echometer, from which the depth is read.

The under-water projector, shown in Fig. 2, is placed in a suitable casing, bolted securely to the ship's bottom; it is open at the bottom to allow the water to come in contact with a metal plate, forming a part of the projector proper.

Underwater Projector

Compressed between two thick steel plates is a mosaic of special crystals in circuit with a special wireless transmitting and receiving set forming a part of the echometer.

When a sounding is to be taken an oscillating voltage is applied momentarily across the plates, causing the outer plate to vibrate at high frequency, and thus to impart a wave motion to the water.

This signal travels to the bottom of the sea and is reflected back again, at a known speed of propagation.

The Echo Signal

When the signal reflected from the

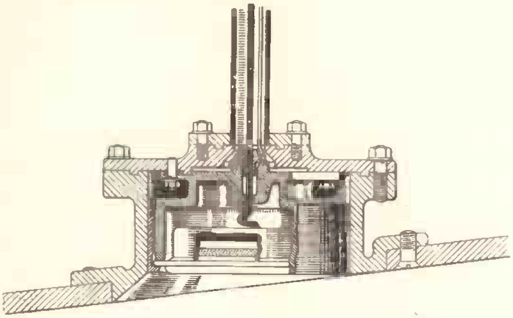


Fig. 2.—UNDERWATER PROJECTOR.

A pulse of high-frequency current causes the lower plate to vibrate, the returning signal or echo sets up a small voltage in the device as explained in the text.

bottom of the sea strikes the projector the reverse process takes place and a small voltage is set up in the projector circuit.

Thus, to measure the depth of water it is merely necessary to measure the time interval between the moment of transmission and the moment of reception of the echo or return signal.

The wireless waves used in this device are supersonic, concentrated into a beam and transmitted vertically, to minimise submarine and parasitic noises.

The Echometer

The echometer consists of the timing and indicating system—the transmitter, and the receiver or amplifier.

The transmitter is very similar to a small type of spark transmitter as used for wireless work; the amplifier also follows, very closely, normal wireless practice and merely magnifies the echo signal received by the projector.

Indicating System

In the top of the echometer case is an opaque sector, graduated from 0 to 360 fathoms. A spot of light from a small electric lamp in the case is reflected on to the scale by means of a revolving mirror and an oscillograph mirror.

A special motor drives the revolving mirror at such a rate that a spot of light runs across the scale at the correct speed for sound waves in water; in other words, the spot of light travels from 0 to 360 on the scale in exactly the time taken for a transmission to go to that depth and be reflected back; actually, the spot of light traverses the scale about sixty times in seventy seconds.

The oscillograph mirror also reflects the spot of light, but in such a manner that when electric current is received in the oscillograph coil, an armature moves the mirror and projects the spot of light upwards.

Installation

A typical installation is shown diagrammatically in Fig. 3, where A is the complete echometer B the projector, C the 4-volt and 80-volt batteries, and D the charging arrangements for maintaining their correct voltage.

Connections between the projector and echometer are made through an hermetically sealed screening tube, properly "earthed" to the metal structure of the hull.

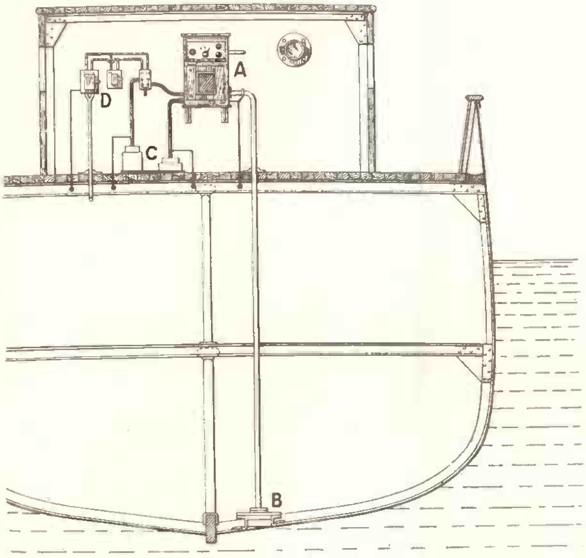


Fig. 3.—ECHOMETER INSTALLATION.

The echometer is shown at A, underwater projector at B; batteries at C; charging board D, and leads to ship's mains.

Lead-covered cables are used for battery leads, and these, as well as all metallic casings, are earthed.

Fig. 4.—PORTION OF INDICATOR SCALE.

A spot of light travels over the scale, the depth of water being indicated by the position of the peak or tooth of light, that at A is the transmission tooth, that at B the echo tooth; its position indicates the depth of water from the surface.

Operation

The echometer is operated by switching on the current which starts up the motor.

Each time the revolving mirror starts it actuates a contact which causes a transmission to be made and causes the oscillograph to move, hence the spot of light on the sector jumps or forms a tooth, somewhat as shown at A in Fig. 4, which is the starting or transmission tooth and is adjusted to occur on the scale at a depth corresponding to the draught of the ship.

Reception of Signal

When the echo returns the amplifier will again energise the oscillograph because the output end of the amplifier is connected across the oscillograph coil; the input end of the amplifier is joined across the projector circuit.

This second or "echo" movement of of the oscillograph causes another tooth in the path of the spot of light on the scale, and it occurs opposite to the graduation corresponding to the depth of water from the surface, somewhat as indicated at B in Fig. 4, hence by merely deducting the draught of the hull—say 2 fathoms, from the second reading, say 50 fathoms, it is seen at once that the depth of water beneath the keel is 48 fathoms. With the machine in motion, automatic soundings are taken at the rate of almost one per second.

NOTES ON THE BROWN A.C. MAINS RECEIVER

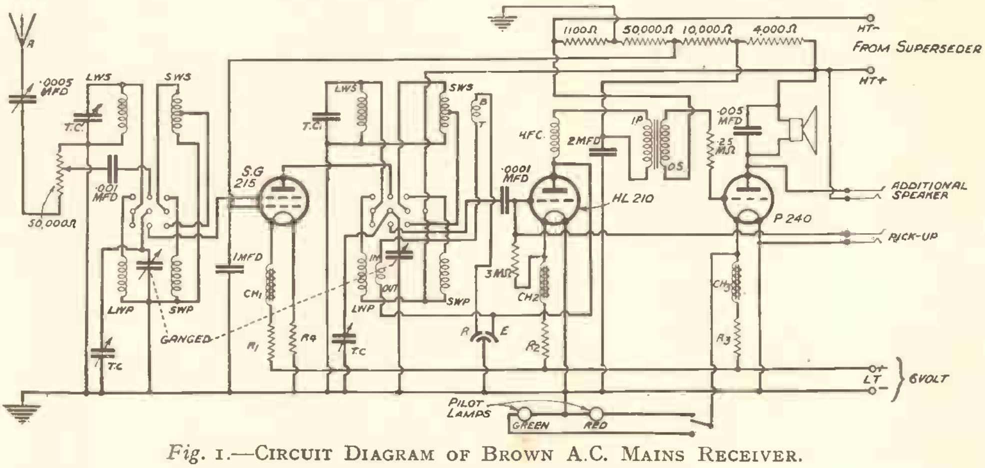


Fig. 1.—CIRCUIT DIAGRAM OF BROWN A.C. MAINS RECEIVER.

OPERATING DATA

Approximate voltages taken with a 1,000 ohms per volt voltmeter between :—

+ and − H.T. at eliminator . .	320 volts, approx.	Anode of Pentode and − H.T. or chassis .	250 volts D.C.
+ and −L.T. at eliminator . .	4 to 4·2 volts A.C.	Screen of Pentode and − H.T. or chassis .	200 volts D.C.
S.G. Anode Terminals and − H.T. or chassis	200 volts D.C.	Outer Terminals of Volume Control .	52 volts D.C.
S.G. Screen Pin and − H.T. or chassis .	70 volts D.C.	− L.T., Earth and Centre Terminal . .	0·8 volt D.C.

SERVICING

THE "HIS MASTER'S VOICE" TRANSPORTABLE RADIO GRAMOPHONE, TYPE 501

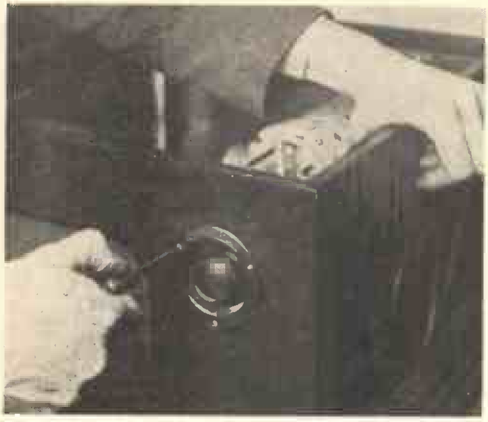


Fig. 1.—Removing Side Knob Escutcheon.

THIS instrument consists of :—

(1) A highly sensitive 3-valve radio unit with :—

Screened grid high frequency valve, Marconi MS4B.

Detector valve, Marconi MH4.

Pentode output valve, Marconi MPT4.

(2) Low resistance, permanent magnet moving coil speaker.

(3) "His Master's Voice" Type 15 pick-up.

(4) "His Master's Voice" Type 24 slow-speed induction Disc motor.

Sockets are provided for additional low-resistance moving coil loud speakers, and the instrument can be operated without an external aerial wire.

This model is for alternating current mains 100 to 160 volts, 200 to 260 volts, 50 to 60 cycles.

The Circuit Arrangements of the "His Master's Voice" 501 Radiogram

The wiring is carried out according to a special code of coloured wiring, which greatly facilitates the following of the circuits.

Colour of Wire.	Function of Wire.
Black	True earth circuit.
White	Cathode when not at earth potential.
Red	H.T. positive D.C. circuit.
Yellow	Anode.
Brown	Heaters, A.C. and D.C. (Not battery.)
Green	Grid. (All grid circuits in A.C. and D.C. mains.)
Blue	Pick-up.
Purple or violet	Aerial.
Pink	L.S. output after condenser or transformer.
Orange	Mains.
Yellow with black tracer.	Pentode screen.
Yellow with red tracer.	Screen of screen grid valve.
Green with black tracer.	Bottom of grid circuit not direct to earth.
Green with white tracer.	Mid position of tuning coil.
Grey	Used for leads not falling within the usual colour code.

The Circuit of the 501

(See Figs. 4 and 5.)

High Tension Supply

A Marconi U.10 full-wave rectifier valve is employed, which feeds unsmoothed D.C. high tension to the smoothing circuit, which consists of a smoothing resistance, R.15 (2,000 ohms), and three smoothing condensers, C.15 (4 mfd.), C.16 (4 mfd.), and C.20 (an electrolytic tubular condenser of 8 mfd.)—C.15 and C.16 are contained in the main condenser "can."

From the output of the smoothing circuit the voltage to the various valves is broken down to the required values, *viâ* :—

R.8 (10,000 ohms) to the screen of the pentode.
R.7 (10,000 ohms) to the anode of the detector valve.
R.11 (100,000 ohms) to the screen of the H.F. valve.

It will be noticed that the pentode anode receives its supply from the rectifier side of the smoothing resistance *viâ* the primary of the output transformer (lugs 3 and 4).

The output of the rectifier system can be checked by a measurement from lug 3 of the transformer to the frame of the unit, since H.T. negative is earthed. The voltage at this point with all radio valves out should be about 380 volts.

The Main High Tension Feeder

This wire, which carries the high tension supply to the various valves and dropping resistances is red and easily distinguishable.

Grid Bias

Bias dropping resistances are employed in all cases. The grids of the valves are in all cases earthed,

In the H.F. valve *viâ* coils L3 and L4 and resistance R.2.
In the detector valve *viâ* the grid leak R.6 and tuning coils L.5 and L.6.
In the pentode valve *viâ* the secondary of the intervalve transformer.

The cathodes of each valve are held positive with regard to earth by resistances R.12, R.14 (H.F. valve), R.14 (detector valve), R.13 (pentode valve).

Low Tension (Heater Arrangements)

The heaters of the three radio valves are connected in common to a 4-volt A.C. winding on the mains transformer (lugs 10 and 12).

It will be noted that the centre point of this winding is earthed.

The Pilot Lamp

This lamp receives its voltage supply from the same winding as the valve heaters (lugs 10 and 12).

The Tuning Circuits

Three tuned circuits are employed :—

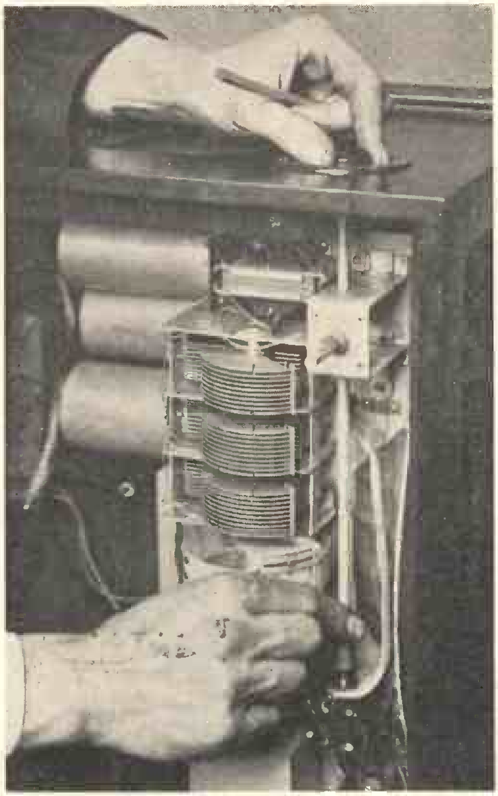


Fig. 2.—Sliding Coupler from Volume Control Shaft before Shifting Volume Control to get at Loud Speaker.

Fig. 3.—Removing Side Knob Extension Shaft.

(1) The aerial coils of the band-pass tuner (L.1 medium wave, L.2 long wave).

(2) The H.F. grid coils of the band-pass tuner (L.3 medium wave and L.4 long wave).

(3) The grid coils of the detector valve (L. 5 medium wave, L.6 long wave).

Switching from long to medium waves is effected by short circuiting out the long-wave coils in tuned circuit by switch contacts "S1," "S2" and "S3."

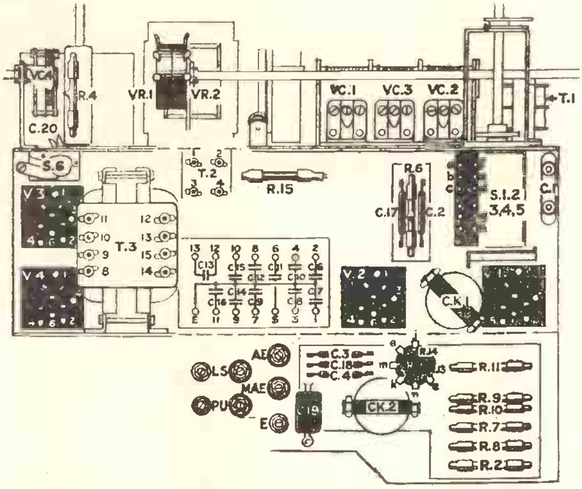


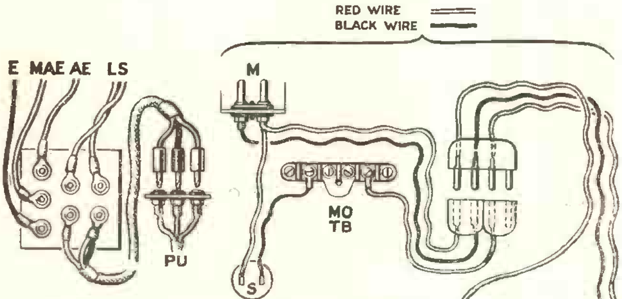
Fig. 4.—Under Chassis Components of His Master's Voice 501 Radiogram.

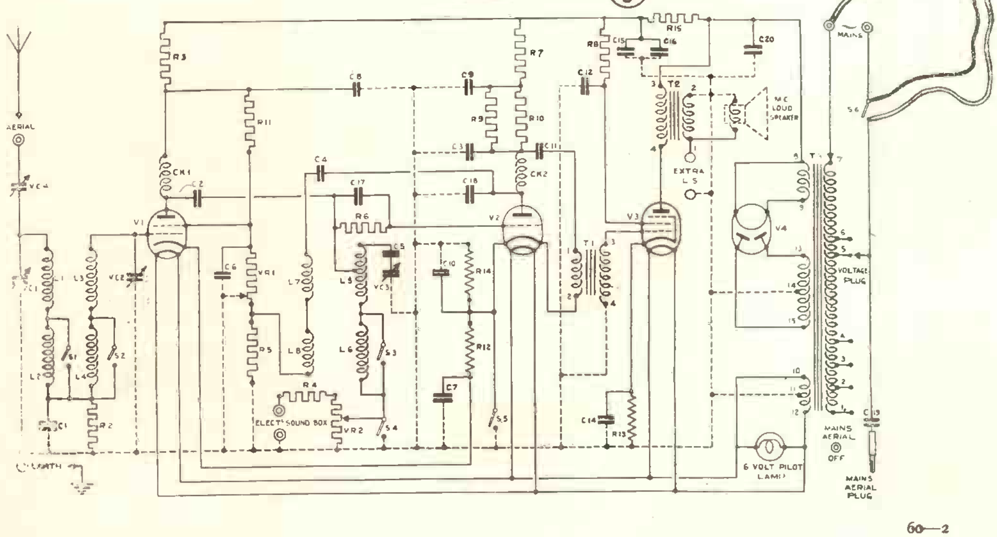
Reaction arrangements

Shunt capacity reaction coils are employed (L7 medium wave, and L8 long wave).

Variation of reaction is achieved by the variable resistance VR1, which is shown in the theoretical diagram in its maximum position. This resistance performs a dual function. When VR1 is at its minimum value to earth, the screen voltage to the H.F. valve *viâ* R11 is partially shorted to earth, and the feed

Fig. 5.—Theoretical Circuit Diagram of H.M.V. 501 Radiogram.





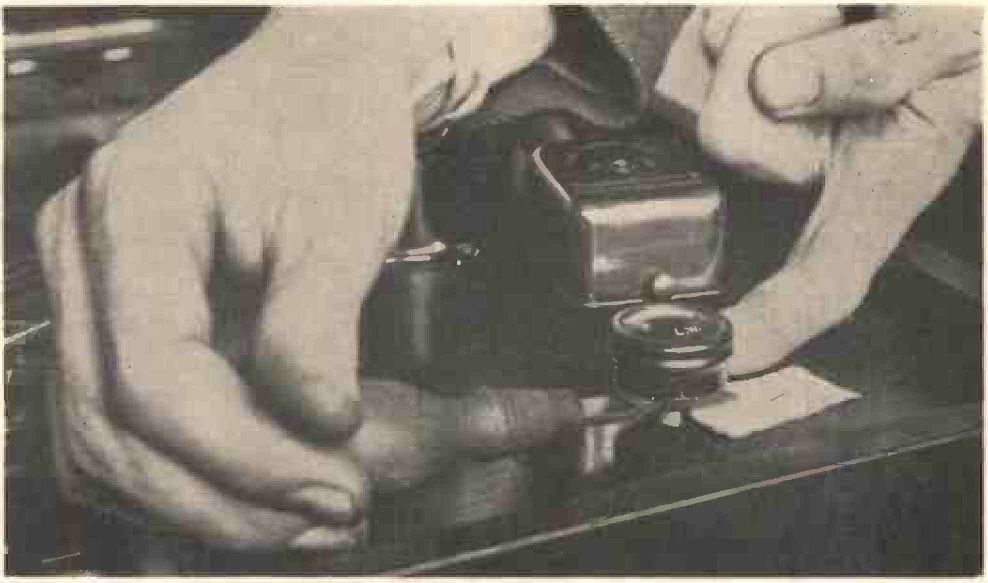


Fig. 6.—THE FIRST OPERATION IN DISMANTLING THE HIS MASTER'S VOICE 501 RECEIVER.

Removing the spring type knobs. The complete process of removing the chassis from the cabinet is shown in Figs. 6–15.

back from the reaction coils reduced by having to pass to earth *viâ* the whole of VR1.

How to Test the Coils

Electrical Values ± 10 *per cent.*

To check continuity of —:

L1 and L2 and switch contact S1 :—

Switch set for "MW" or "Gram" . . . 4·5 ohms
Switch set for "LW" . 27·0 ohms

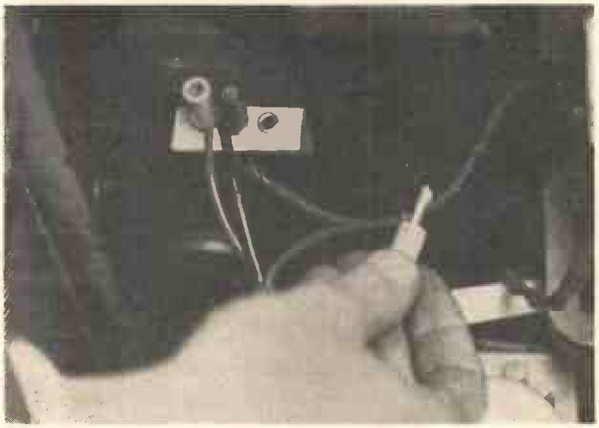


Fig. 7.—REMOVING PICK-UP PLUGS.

(Measure between green lug terminal of C1 and green lug of VC1.)

L3 and L4 and switch contact S2 :—

Switch set for "MW" or "Gram" . . . 4·5 ohms
Switch set for "LW" . 27·0 ohms

(Measure between green terminal of C1 and grid lug of MS4 B holder—V1.)

To check continuity of :—

L5 and L6 and switch contacts S4 and S3 :—

Switch set for "MW" . 4·5 ohms
Switch set for "LW" 27·0 ohms
Switch set for "Gram" Open circuit

(Measure between chassis frame and green shielded lug of C5.)

L7 and L8 (reaction coils) . 15·0 ohms

(Measured between two outer yellow lugs on former in coil can.)

Aerial Trimmer.

Signals are fed to the aerial coils *viâ* the small variable condenser VC.4.

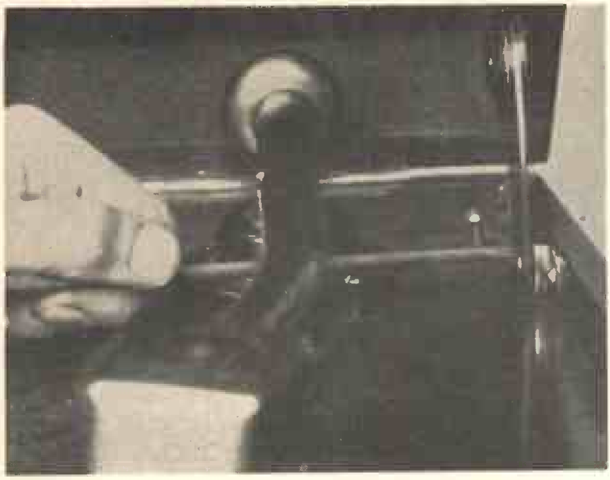


Fig. 8.—Removing the Hinge.

Testing the Valves

The table on page 942 gives the voltage to be expected at the valve holders and the approximate emission of the valves when working correctly.

When making tests on a "live chassis" it is a good plan to extract the pilot-lamp holder from beneath the tuning scale and place it where it can be clearly seen as a warning when the chassis is switched on.

How the Mains are Connected to the Chassis

The chassis obtains its supply from the twin pins on the motor board *viâ* a 4-pin plug, only three pins of which are in use ; the plugs making it possible to remove the motor board complete with motor and pick-up without disturbing the radio unit. The course of the supply is as follows :—

Motor board mains pin.

Red wire to left socket of left pair of motor-board sockets.

Left pin of left pair of plugs attached to triple flex.

Red wire to one mains pin on chassis, flexible rubber lead, and transformer primary tapping plug.

Mains transformer primary.

Out of transformer primary *viâ* other tapping plug to right-hand side of switch and through switch *viâ* black wire, to right-hand pin of *left*-hand twin plug.

Right-hand socket of *left*-hand pair of motor-board sockets through black wire to other cabinet mains pin.

How the Mains are Connected to the Motor

Motor board mains pin.

Red wire to one side of tone arm switch.

Black wire from other side of tone arm switch to one side of the motor terminal board.

Red wire from other side of motor terminal board to left-hand socket of *right-hand* pair of sockets on motor board.

Red wire from left-hand pin of double plug attached to triple flex to right-hand side of switch on chassis (looking from top of chassis.)

Through switch *viâ* black wire to right-hand socket of *left-hand* twin plugs attached to triple flex.

Right-hand socket of *left-hand* pair of motor board sockets to other mains pin *viâ* black wire.

The Correct Way to Remove the Radio Unit

(1) Remove back board.

(2) Gently lever off (if no grub screw) "volume control" and "aerial tuner" knobs and remove circular moulded escutcheons ; also "gramo-radio" switch and tuning knob on motor board.

(3) Lift off turntable.

(4) Extract blue and black pick-up plugs on underside of motor board.

(5) Extract double motor plug (red and black wiring) on underside of motor board.

(6) Remove lower hinge of lid stay from cabinet and *carefully* rest lid back on its hinges.

(7) Unscrew four motor-board retaining screws (in corners), and lift out motor board by grasping *base* of pick-up and lifting knob on left-hand side of board.

(8) Unscrew and remove two hexagonal nuts of chassis-retaining bolts on bottom of cabinet.

(9) Remove two hexagonal bolts holding

Valve Table

Volume control full on. Readings Approximate. Valves in and alight unless stated otherwise.

Valves.	Location from Rear.	Appearance.	Temp.	Function.	Anode Current.	Avo Scale.	Anode Volts to Frame (D.C.).	Avo Scale.	Screen Current D.C. m/A.	Avo Scale.	Screen to Frame Volts (D.C.).	Avo Scale.	Grid Bias Volts.	Avo Scale.	Fil. or Heater Volts.
MS 4 B	Left	No glow	Just warm	Screened-grid grid H.F.	1·5 m/A. (between tag and top terminal of valve)	·012	150·0 (tag to frame of chassis)	1,200 V	·5 m/A (anode socket of holder to anode pin of valve) (adaptor)	·012	40·0	1,200 V	— 1 Grid to Cathode	120	4·5 A.C
MH 4	Centre	No glow	Warm	Detector	2·0 m/A. signal tuned in	·012	55 V	120 V.	—	—	—	—	·2 Grid to Cathode	1·2 V	4·5 A.C.
MT 4	Top Right	Slight glow	Hot	Pentode Output valve	25·0 m/A.	·12	280·0	1,200 V	3·5 m/A.	·012	150·0	1,200 V	— 1·3	12 V	4·5 A.C.
U 10	Bottom Right	No glow	Warm	Rectifier	16·0 m/A. each anode	·12	A.C.	—	—	—	—	—	—	—	4·5 A.C.

Notes.—Values especially of grid bias are not necessarily "Actual," but are as indicated on Avo Scale given.

Variations of at least 10 per cent. may be expected in valves.

Voltages to be found at the Valve Holders with all Valves out except the U10 Rectifier Valve.

Valve Holder.	—	Volts.	Avo Scale.	Remarks.
MS 4 B	Grid socket to frame	No indication with valve out.	—	The bias on this valve depends on the anode feed of the valve. See Valve Table.
	Anode socket to frame	75 V.D.C.	1,200 V.	—
	Across fil. sockets	4 volts A.C.	—	—
	Anode tag to frame (rubber lead).	310 V.D.C.	1,200 V.	—
MH 4	Grid socket to frame	No indication with valve out.	—	See MS 4 B.
	Anode socket to frame	240 volts D.C.	1,200 V.	—
	Across fil. sockets	4 volts A.C.	—	—
MPT 4	Grid socket to frame	No indication with valve out.	—	See MS 4 B.
	Anode socket to frame	380 volts D.C.	1,200 V.	—
	Across fil. sockets	4 volts A.C.	—	—
	Screen tag (rubber flex) to frame.	300 volts D.C.	1,200 V.	—

Fig. 9.—Lifting off the Motor Board.

Fig. 10.—Removing Bottom Bolt while supporting Radio Unit with Left Hand.

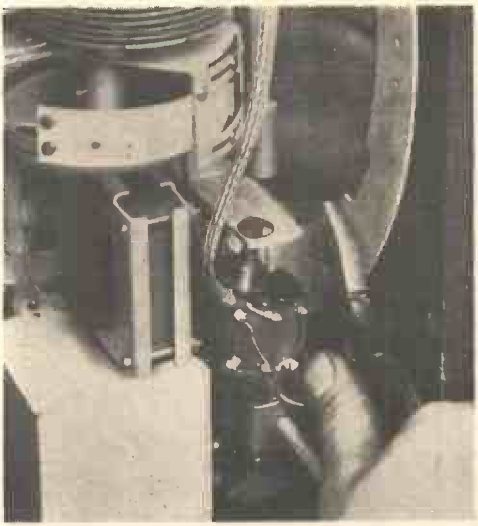


Fig. 11.—Unscrewing Loud Speaker Bolt with Volume Control moved out of the way.

Fig. 12.—Slackening off Volume Control Securing Nut.

top of loud-speaker frame to baffle. (Do not loose metal sleeves.)

Note.—To unscrew bolt near volume control proceed as follows :—

A. Slacken grub screw securing volume control spindle to operating rod.
B. Slide back rod.
C. Slack off volume control locking nut.

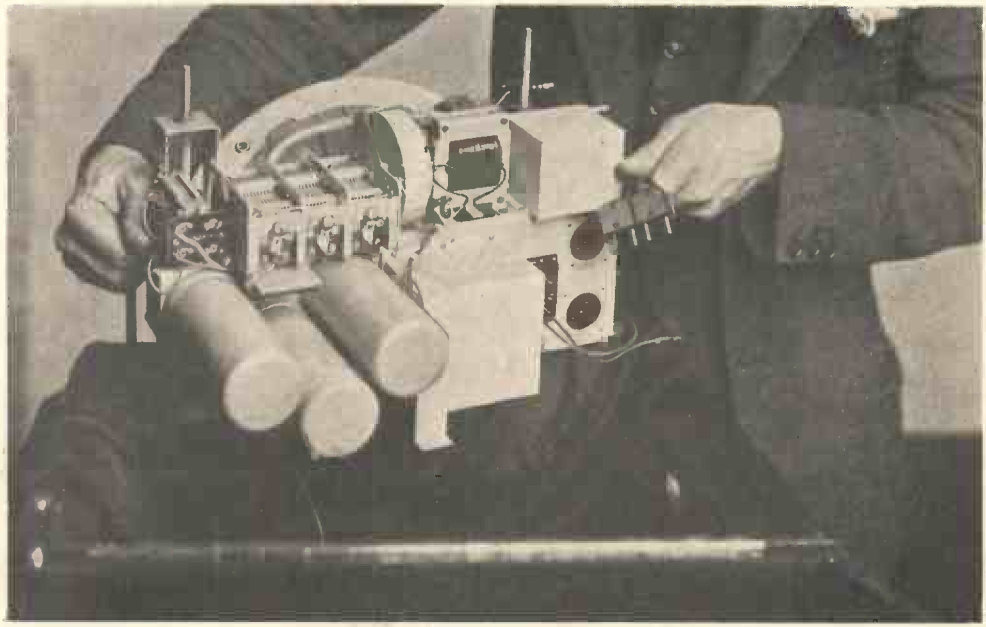


Fig. 13.—Lifting Out the Radio Unit.

Note edge of cabinet protected by cloth.

D. Withdraw volume control carefully from bracket and place on one side, to make room for spanner on hexagonal bolt.

(10) Slacken grub screws and remove small extensions on trimmer and volume-control rods.

(11) Remove armoured cable clip and wood screws holding metal bracket supporting aerial and earth, etc., sockets to bottom of cabinet.

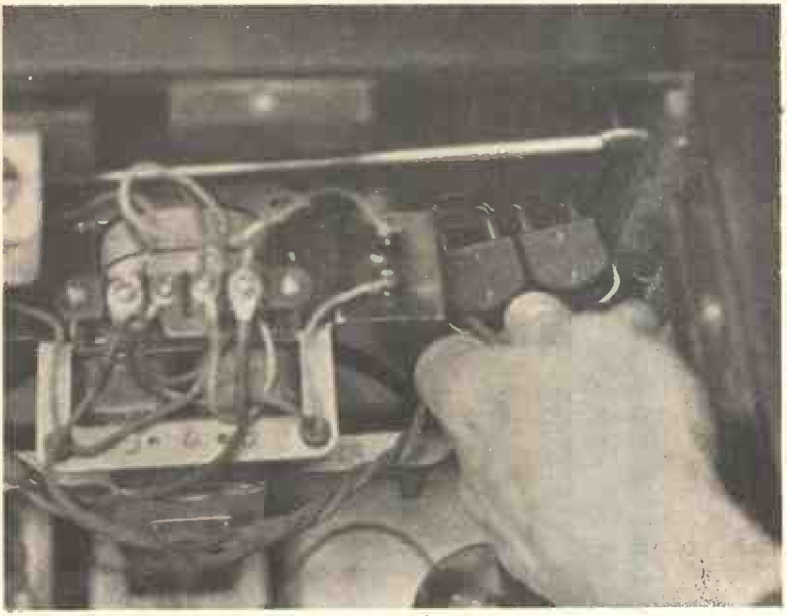


Fig. 14.—Removing Motor Plugs.

How to Lift Out the Unit

(12) Place left hand under *fixed* condenser block (*not* ganged condenser), and crook fingers of right hand in metal operating rod supporting bracket, and lift out chassis complete with all leads and metal bracket.

(13) Rest chassis on edge of bench so that volume control spindle is clear of edge. Reassemble volume control on bracket.

The following parts are now available for inspection :—

Mains switch.

Motor supply plugs (red and black wire).

Pick-up leads (armoured).

Aerial, earth and extra loud speaker sockets and leads.

Paxolin adaptor plate for above.

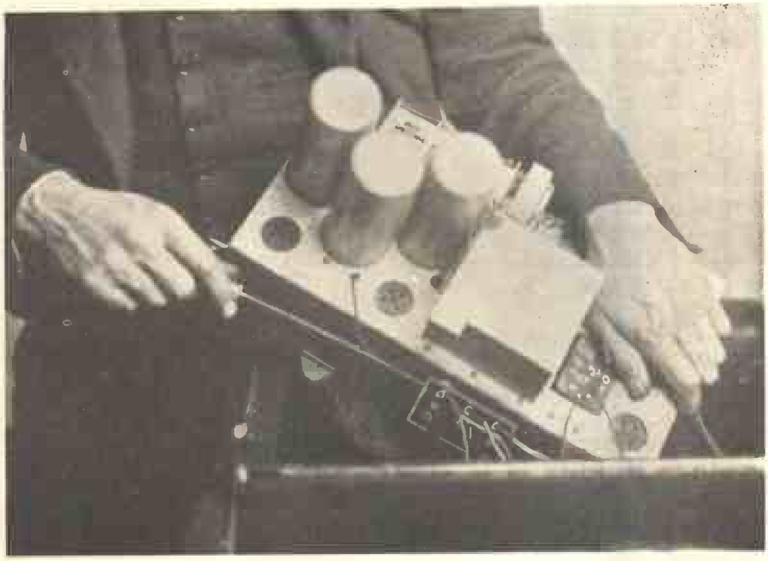


Fig. 15.—The Final Operation in removing Chassis from Cabinet. Removing the adaptor plate.

(14) Gently lever off adaptor plate.

(15) Unscrew two bolts holding loud-speaker frame (holding loud speaker unit to prevent it falling).

(16) Remove loud speaker and rest face down on bench *without cutting* wires or removing dust bag.

The interior of the instrument is now exposed.

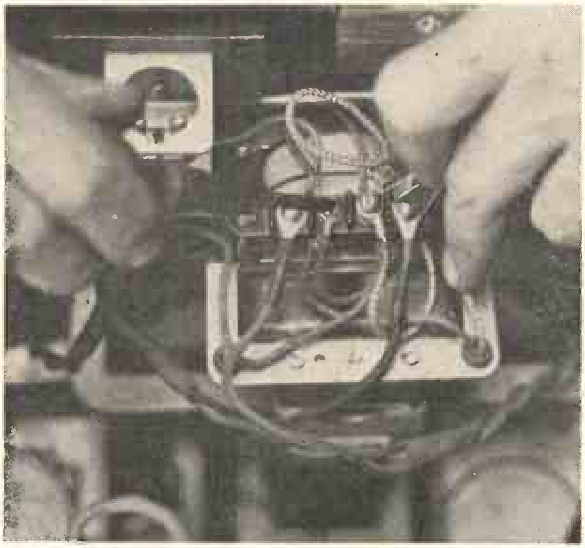


Fig. 16.—Adjusting the Motor Voltage.

The chassis may now be tested without the motor board by inserting the mains supply plug on to the chassis mains supply pins opposite the mains switch.

Warning.—When doing this insert the twin motor plugs on red and black flex, in an envelope or otherwise insulate to prevent short circuit from pins on chassis frame.

How to Test through the 501 Circuit to Locate a Fault

(1) Check to see that the loud speaker is O.K.

(2) Tap detector valve to see if a slight ring is heard in the loud speaker or test headphones.

If set is absolutely dead, suspect H.T. supply, *i.e.*, U.10 rectifier mains transformer and main high tension feeder and associated smoothing resistance R15, and condensers C15, C16, C20. First test voltages at valve holder by the table on p. 942, then check voltage dropping resistances and smoothing condensers by the table (p. 947) which enables you to trace back the voltage supplies to the valve holders.

Note. — R13 "dis" would prevent current flowing through pentode, and R14 the detector valve.

If the H.T. supplies *and valve emission* are O.K. this will indicate that resistances and transformer primaries in anodes circuits of valves are O.K., and that bias resistors are O.K.

How to Test Low-Frequency Sections (Detector Valve, Output Valve and Output Transformer)

1. Test Signal from a Record

If no ring is now heard in the loud speaker or test phones, employ pick-up to supply a test signal from a record, and turn volume control to maximum.

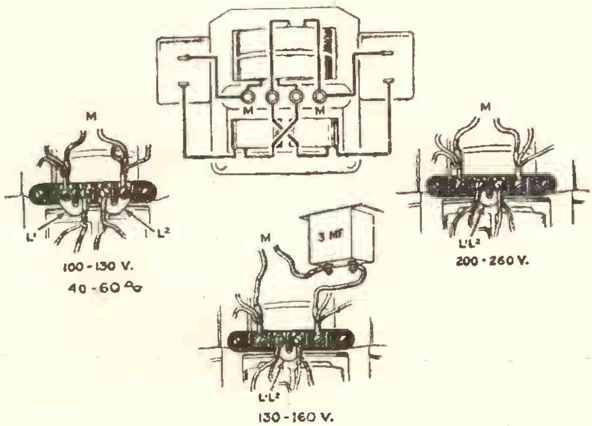


Fig. 17.—The Motor Connections.

2. Test Signal to Grid and Cathode Sockets

Ensure that pick-up music is reaching the grid and cathode sockets of the detector valve

THE 501 HIGH TENSION SUPPLY CHECK CHART

SPECIAL NOTES.

See that flexible leads to valves are not touching chassis.
See that twin motor plugs cannot touch chassis.
All components underlined are those which if shorted will short circuit HT + to earth.
Test these components for breakdown to earth. Voltages measured from Test-points to Frame (and with Volume Control at maximum). (U 10 valve *only* inserted.)
(Electrical readings, ± 10 per cent.)

Fil. Lug U10 holder
red wire
Lug 1—C20 (smoothing cond.)

Pentode anode circuit

Red wire

Main HT + Test Point Red wire on C20 (approx. 380 volts)

Primary T2 (1,000 ohms)
Yellow wire

ANODE SOCKET PENTODE HOLDER

R 15 (black)

Lug 10 cond. block (smoothing cond. C 15 to E)

Lug 11 cond. block (C16 smoothing cond. to E)

Red wire

Pentode screen circuit

R8 (on rack)
Yellow and black wire (300 volts)
Lug 8 cond. block (C12 to E)
Rubber Lead with tag for Pentode screen terminal (300 volts)

Det. anode circuit

R7 (on rack)

H.F. *screen circuit*

R 11 (on rack)
Red and Yellow wire
Vol. control (45 volts)
Lug 2 cond. blk. (C6 to E)
Screen socket of H.F. valve holder (80 volts)

H.F. anode circuit

Red wire (or brown)
H.F. C.K.1
C2 to L5 and 6 and E
Rubber lead and tag for anode terminal on top of MS4B H.F. valve (300 volts)

Lug 7 cond. block (C9 to E)

R9. R10 (in parallel on rack)
Red wire

Red wire
Lug 5 cond. block
(other side Lug 6 to intervalve Trans.—T1)
(Yellow wire)

C3 (·001)
Black wire to E *viâ* switch contacts, etc.

H.F. chokes C.K. 2 (250 volts) Yellow wire

C.4 (·0002)
Yellow wire
L.7, L.8

Anode socket of detector holder (250 volts)

C.18 (·0002 mfd.)
(E *viâ* Lug of C. 3)

Note.—No H.T. volts or very low readings and humming from the mains transformer indicates a condenser broken down to earth.

holder by inserting test phones there.

3. Test in Anode Circuit of Detector Valve

Re-insert detector valve and, either with a valve-testing adaptor or by unsoldering one side of the H.F. choke CK2, insert the headphones in the anode circuit of the detector valve. Signals louder than before should be heard; if not, check up valve and valve-holder contacts.

Fig. 18.—ADJUSTMENT OF RATCHET PLATES.

4. Test Signal to Primary of Intervalve Transformer

This is resistance capacity coupled to the anode circuit of the detector valve by R10 and C11.

Place test phones between coupling condenser C11 and primary of T1 by unsoldering wire to lug 1 of the transformer. If no signals are heard, check continuity of winding and C11 for breakdown to earth.

5. Input to Pentode Valve

Place test phones in grid and cathode sockets of the pentode valve; if no signals, check up secondary winding of the intervalve transformer and connections to pentode valve holder.

6. Testing the Output to Pentode Valve

The anode circuit of this valve may be cut between the lug 4 of the primary of the output transformer and the anode socket of the valve holder or a valve-testing adaptor employed. If no signal is heard and a signal has been heard at the input to the valve, the valve is almost certain to be defective internally, or possibly the valve pins are not making contact with the valve-holder clips. Also check the voltages to the screen and anode of the valve.

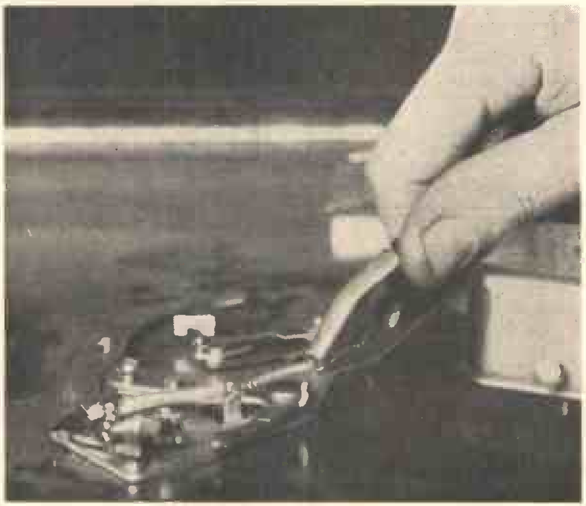


Fig. 19.—ADJUSTING THE BRAKE SWITCH RATCHET PLATE SPRING.

Testing the Output to the Loud Speaker

Connect the test phones to the loudspeaker connections of the secondary of the output transformer, and if necessary check the continuity of the secondary winding. If this winding, its connection to the coil of the loud speaker or the coil of the loud speaker has become "dis," damage may have been done to the pentode valve internally, and a new valve should not be fitted until the necessary repairs have been made to the coil or transformer.

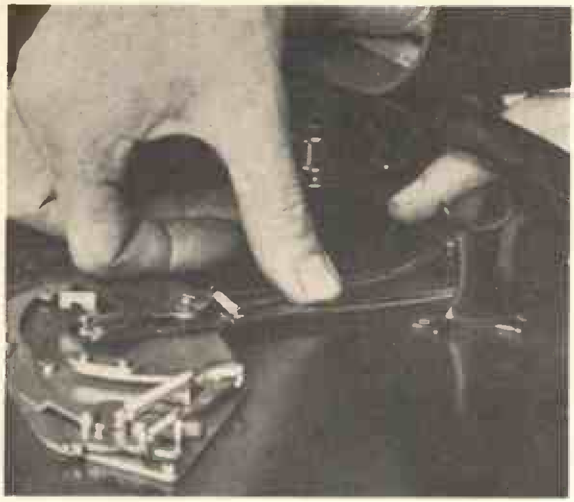


Fig. 20.—Disengaging the Brake Lever from the Pick-up.

How to Test the Radio Frequency Circuit of the 501

It is not possible to hear audibly the radio frequency currents flowing in the tuning coils and other components which precede the detector valve. The following things can, however, be done :—

(1) Check the "services" to the valve, *i.e.*, high tension and low tension.

(2) Check the emission of the valves.

(3) Having ascertained that the local station is transmitting, and that the detector and low-frequency side of the circuit is O.K. by pick-up signals, connect the aerial in turn to each tuned circuit and listen for signals in the loud speaker or test phones.

Example—

The instrument will not give good reception on medium waves.

A glance at the diagram shows that in the medium-wave position the long-wave coils L2, L4 and L6 are shorted out by the wave-change switch.

One of the switch contacts may not be making correctly, or there may be a disconnection in one of the long-wave coils.

Fig. 21.—Increasing the Pressure of the Brake Friction Washer.

How to Find the Defective Tuning Circuit

Detach the aerial wire from the set and clip it first on the fixed vanes of VC1 (electrically to the top of L1), if no signals are heard transfer the aerial to the top of coil L3 by clipping on to the fixed vanes of VC2 ; if signals are heard here—tuning will be flat—examine the coil L2 and the switch contacts C and B of S1.

If no signals are heard, clip on to the coil L5 *viâ* the correct side of R4 or C17 (a contact to the variable condenser cannot be used because of the "padding" condenser C5). Signals here will not be so loud as usual because the H.F. valve has been eliminated, and tuning will be very flat, since the set is now being used as a simple single-tuned circuit.

Note.—The signal can also be fed to the grid circuit by clipping on to the anode terminal on top of the H.F. MS4B valve.

This method will be found to be of great value in testing the tuned circuits of all sets of this type.

The Pick-up Circuit

If no gramophone reproduction is found, but radio is O.K., the trouble is certainly connected with the pick-up.

How the Pick-up is Connected

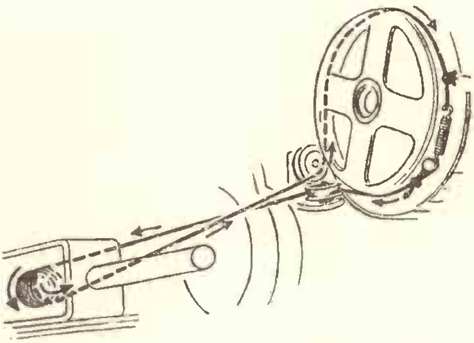


Fig. 22.—Details of the String Drive.

The wires from the pick-up are connected to three sockets, into which plugs are fitted to enable the motor board to be lifted out without disturbing the chassis. Take out the plugs, and with the pick-up playing a record, place the test phones across the two outer sockets (blue) and listen; if clear music is heard here, re-insert the plugs and test the sockets on the transfer plate and their connections to the radio unit.

One Side of the Pick-up is Earthed

Since one side of the pick-up is earthed, a short circuit to earth of one of the leads from the pick-up would stop signals. If, however, signals are heard at the sockets, reconnect the plugs and listen across the outer ends of the volume control VR2. This will check the continuity of R4, and signals will *not* be affected by moving the volume control knob. Then test across the centre lug and one end lug of the volume control; signals here will be varied by the volume control.

Testing the Switch for "Gram" Position

A further test can now be made between earth (frame of unit) and each side of R6. Check the continuity between the volume control and that point and switch contacts F, G, E and H and coil L5.

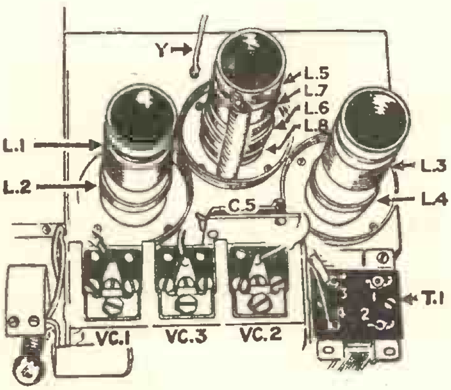


Fig. 23.—The Tuning Coils and Condensers.

Adjustment of Tone Arm Operated Brake

(1) Switch off current.

(2) Move tone arm so that switch is "OFF."

(3) Remove back cover by unscrewing two securing screws.

(4) Examine, and clean if necessary, spring contacts on interior of moulded cover.

(5) Clean and examine rotating contacts on shaft of motor.

(6) When re-assembling rotary contacts see that small arm of contact engages in slot in metal-operating plate (on top of motor board).

(7) When replacing cover, see that switch is in "OFF" position, and exercise care so that when switch is moved the rotary contacts engage correctly with spring contacts on moulded cover and do not jam.

Warning.—If a jam does occur, under no circumstances force tone arm or switch-operating levers. Remove moulded cover again and re-assemble as before.

The 501 Motor for A.C. Mains

This motor is the "His Master's Voice" type 24, and full details are given for its adjustment and examination in the service notes on the "His Master's Voice" Radio Gramophone, type 521, on page 252 of Vol. I of Complete Wireless.

The 501 Pick-up

This is the "His Master's Voice," type 15 pick-up, full details of which will be found on page 247 of Vol. I of Complete Wireless.

The 501 Fault-Finding Table

Symptoms.	Suggested Cause.	Suggested Remedy.
Scale does not light up.	Defective lamp. Lamp out of holder.	Change lamps.
Scale light flickers. **Crackling with Radio reproduction.**	Lamp loose in holder. Lamp loose in holder. Defective lamp.	This lamp is of the 6-volt screw-in type. To replace a lamp it is advisable to remove the chassis from cabinet, especially if crackle is thought to be due to faulty contacts on lamp holder. If a lamp is found to be unduly slack in the holder, a strip of paper approximately ½ inch wide should be held against the inside of socket, and after lamp has been screwed up tight the surplus paper torn off. **Note.**—In certain instruments, the lamp holder (which is attached to the flat lever projecting from left-hand side of motor) is not welded in position, and by turning tuning knob to minimum wavelengths and pushing flat lever upwards, the lamp assembly may be withdrawn. When reassembling, fit the fork end of lamp bracket assembly over the spindle of condenser drum and push the clip of bracket down on to frame of variable condensers. Before finally replacing chassis and replacing back of cabinet make certain that when the tuning knob is turned the screws in the drum boss do not touch any part of lampholder or connections. *Should these screws touch lampholder or wiring to same, the filament winding of the mains transformer will be shorted to earth and serious damage may result.*
	Loose valve holder clips.	Bend together.
Condenser vanes will not rotate below a certain point on the scale.	(1) The moving condenser vanes may have fouled the switch indicator plate, so that the knob, in an effort to turn the scale, has been turned so that the string drive has slipped. (2) One of the small earthing clips inside the variable condenser chassis may be touching the moving vanes. Proceed as follows :—	(*a*) Remove chassis and slack off lower grub screw of tuning knob driving spindle. (*b*) Carefully and without damaging the moving plates in the condenser, open them to their fullest extent. (*c*) Turn the tuning knob in an anti-clockwise direction as far as it will go. (*d*) Re-tighten the lower grub screw. *Note.*—It is not wise to force the tuning knob in the reverse direction as this may damage the rotating stop on the tuning knob spindle. Failure to rotate the tuning scale completely or stiffness at any one point on the scale may be due to the fact that one of the three stops is either over-riding the next one, or jamming on it.
Tuning knob will not turn wavelength scale.	Broken scale driving cord (see Fig. 22)	Replace cord as follows :— (1) *Type of Cord.*—Employ a superior flax fishing line having a breaking strain of approximately 40 lb. Approximate length, 31 inches. (2) Double back 1 inch of cord and tie a knot so that a loop end is formed. (3) Fully disengage condenser vanes and turn tuning control spindle as far as possible in an anti-clockwise direction. (4) Put the loop end of cord over small stud on condenser drum and wind cord in the direction indicated by arrow. A STIFF PIECE OF COPPER WIRE WITH A HOOKED END WILL BE FOUND USEFUL IN MANIPULATING THE CORD.

THE 501 FAULT-FINDING TABLE—*continued*

Symptoms.	Suggested Cause	Suggested Remedy.
		There should be six complete turns on the tuning control spindle which should not overlap one another. *Important.*—The tuning control spindle must be kept to its anti-clockwise *stop* position while cord is being assembled. (5) Pull the cord tight, double back 1 inch and tie a knot so that a loop is formed on end. The loop end should be adjusted so that the coils of tension spring are opened when the spring is assembled on the stud.
Failure of radio reproduction, or noisy movement on aerial selectivity control, on left-hand side of instrument.	The washers insulating the spindle of this condenser from the bracket on which it is mounted being cracked or displaced ; or Selectivity control has been overturned and the contacts touching chassis or other components thus shorting the aerial terminal to earth.	Remove unit and carefully examine mounting of condenser, also see that insulating bushes are intact. Remove leads from condenser, having finally mounted it, and make a test of bracket from the chassis to the moving and fixed vanes of condenser before replacing leads. Be careful to screw up the single nut securing the condenser on the bracket as firmly as possible without damaging the insulating washers, finally testing washers again to see that they are not broken or causing a short circuit between the spindle and the bracket. *Note.*—In the event of fresh washers not being available the condenser may be temporarily insulated by winding some insulating tape round the shaft and carefully screwing up the securing nut and washers. This must, however, be considered as only a temporary expedient. *Important Note.*—Before reassembling the chassis the switch indicator plate should be examined to see that there is no possibility of its touching the moving vanes of the variable condenser. If there is, plate should be slightly bent forward, but not so far that it will foul on the interior of the cabinet.
Crackling switch poor "LW" or "MW" Radio.	Switch requires adjustment or cleaning.	(1) Remove chassis from cabinet. (2) Turn the switch until the indicator (or knob) is in the "GRAM" position. The two grub screws in the switch barrel should now be visible. *To clean switch* :— (1) Unsolder the wires attached to the switch, labelling each carefully for reassembly. (2) Remove the four screws fixing the insulating panel holding the spring wire contacts and clean the contacts with fine emery cloth. (3) Slack off two grub screws holding switch barrel. The barrel should now revolve freely on the spindle. Clean wire contact bars with fine emery cloth. Remove every trace of cleaning material before reassembling. *To replace switch* :— (1) Tighten two grub screws on switch barrel, making sure that they locate in the dimples in spindle. (2) Replace the insulating panel with contacts, bending the contacts inwards if necessary, and resolder wires on to contacts. Smear all contacts with PURE vaseline. (3) Make sure that the grub screws in the main switch cam, and the indicator cam, are tightened down into their dimples. With the switch in the "GRAM" position these grub screws are accessible.
Stiff switch.	Switch indicator plate fouling the moulded scale window escutcheon.	Examine to see if switch position indicator plate is fouling moulded escutcheon. *Note.*—When adjusting, do not bend back so far that movable vanes of gang condenser touch indicator plate.

Special Notes with Regard to Measuring Resistances of Components Given Below

DO NOT MEASURE RESISTANCES :—

A. With set " Live."
B. Component Undisconnected from the Circuit.
C. Valves or pilot lamp in.

Components.	Where to Measure.	Approx. D.C. Resistance – 10 per cent.
CK1 " H.F." Choke.	Across Choke.	85 ohms.
CK2 " H.F." Choke.	Across Choke.	85 ohms.
R14.	Frame and white lug " J " (2nd from Black lug) or switch contact " e."	1,000 ohms.
R13 (" n " and " e.")	Frame and white lug next to black wire.	250 ohms.
R12 (" m " and " k ").	White switch lug and 3rd white lug from black lug on bobbin.	600 ohms.
Intervalve Transformer, Primary.	" T1." Lugs 1 and 2.	1,000 ohms.
Intervalve Transformer, Secondary.	Lugs 3 and 4.	10,000 ohms.
Output Transformer, Primary.	" T2." Anode socket of Output Valve and one side of " R15."	1,000 ohms.
Output Transformer, Secondary.	Ext. Loud Speaker Sockets (having disconnected cabinet loud speaker by removing Block).	0·9 ohm. approx.

The 501 Loud Speaker

This is fully described on page 257 of Vol. I of Complete Wireless.

It is a permanent magnet moving coil loud speaker. The principle of operation is that if a coil of wire carrying an electric current is placed in the field of a magnet and the current varies in the coil, the coil would tend to move with regard to the magnet, and if therefore the coil is attached to a cone, the cone will move, causing air waves which will give an air-wave reproduction of the electrical current variations in the coil.

In order that the greatest possible efficiency may be obtained, the air gap between the poles of the magnet is very small, and it is necessary that the coil should be correctly centred in this gap so that it can move in and out without touching the sides of the poles.

Full instructions for making sure that the cone and coil is correctly central in the gap are given on p. 258.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION X—AERIALS AND AERIAL DESIGN (2)

IN Section IX we dealt in some detail with open aerials and their operation on frequencies greater and less than the natural, or resonant, frequency of the aerial. We shall devote this section to a discussion of tuned frame aerials, *i.e.*, closed aerials, of dimensions small in comparison with the lengths of the waves considered. Most readers will be familiar with long-wave and medium-wave frame aerials, and will know that suitcase portables, and some transportable receivers, embody a frame aerial within the suitcase lid or cabinet. The essential feature of the frame aerial is its directional properties, *i.e.*, it does not respond to a signal equally well in all positions of the frame. It is usual to mount the frame so that its plane is vertical and so that it rotates about a vertical line, or axis, taking up successive positions as shown in Fig. 1 at (*a*), (*b*) and (*c*).

Positions for Maximum and Minimum Signals

Suppose that we have a medium-wave frame aerial connected to a receiver which is tuned to the local station signals. If we rotate the frame—away from buildings and metal structures such as in a garden or in a field—we shall find two distinct positions of the frame which give no signal, and two positions giving a maximum signal. The zero signal positions will be fairly well defined, and the maximum signal positions vaguely defined. Let us draw a plan of the ground showing the directions of the frame for maximum and minimum signals. We shall find that a maximum signal is obtained when the frame points towards the local station, and a minimum signal when the direction of the frame is at right angles to the bearing of the local station. These positions are shown at (*a*) and (*b*) of Fig. 2. Two positions of maximum and minimum signal are obtained, because there are two ways of pointing the frame in each case.

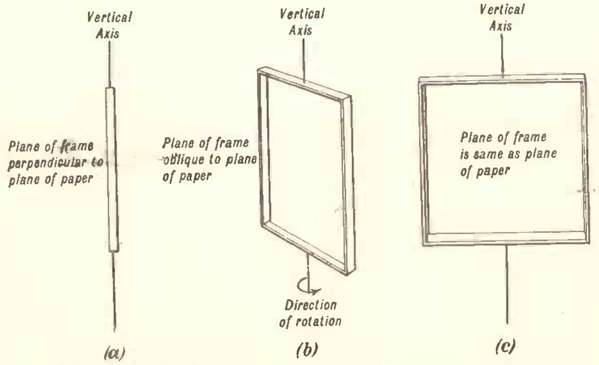


Fig. 1.—THE DIRECTIONAL PROPERTIES OF A FRAME AERIAL.

Frame Aerial Possesses Inductance and Resistance

The frame aerial itself is actually a large size in coils. Its two ends are joined to the terminals of a condenser and the parallel circuit so formed is connected in the input circuit of the receiver in place of the usual tuning circuit comprising coil and condenser. The frame possesses inductance and resistance in precisely the same way as the smaller size of coil, and the parallel circuit, shown in Fig. 3, is tuned, and responds, in a manner identical with that of the parallel circuit discussed in Section VII of this series (see Fig. 6, Section VII).

Resonance Condition for a Tuned Loop

The resonance condition

for a tuned loop is the same as that for a coil, viz.:

$$Lw = \frac{1}{Cw} \quad . \quad (1)$$

where L is the inductance of the loop in henries, C is the capacity of the tuning condenser in farads, and w is the angular frequency of the incoming signal. That is to say, the frame is "in tune" with the signal whose angular frequency is w if the inductance, capacity and angular frequency are such that Lw equals $\frac{1}{Cw}$. As before, this condition can be expressed more conveniently as:

$$\lambda = 1885 \sqrt{LC} \quad . \quad . \quad . \quad (2)$$

where λ is the wavelength of the incoming signal and L and C are measured in microhenries and microfarads respectively.

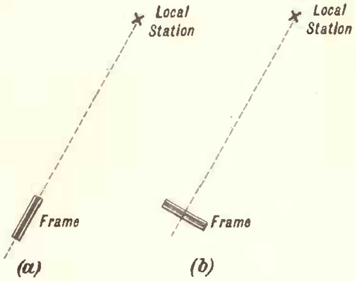


Fig. 2.—The Two Positions where Maximum and Minimum Signals are obtained.

Formula for calculating Inductance of a Frame Aerial

Thus the problem of designing a frame aerial is the same as that of designing a coil of large dimensions having an inductance approximately equal to that of the coil which would be used in the normal tuning circuit. The formula which we have already employed for the calculation of the inductance of a single layer coil wound on a former of circular section—see Section V of this series, equation (2)—can be used for the calculation of the inductance of a frame aerial. For convenience of reference, the formula is reproduced again:

$$L = 9{\cdot}87 \times 10^{-3} \times \frac{d^2N^2}{l} \times K \quad (3)$$

where L = the inductance in microhenries.
d = diameter of loop or coil in centimetres.
N = total number of turns of wire on loop or coil.
l = total length of winding in centimetres.
K = a number depending on the ratio of d to l, and given in the table on p. 559, Vol. II, of Complete Wireless.

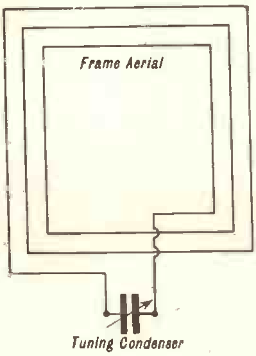


Fig. 3.—Showing how a Frame Aerial is tuned in a similar manner to a Coil.

Since most experimenters naturally express all their measurements of length in inches, it will be more convenient to rewrite (3) so that both d and l are in inches. We have:

$$L = 2{\cdot}505 \times 10^{-2} \times \frac{d^2N^2}{l} \times K \quad (3a)$$

If the frame is of square section (3) and (3a) can again be used for the calculation of the inductance. The inductance value required is approximately 1·23 times that of a frame of circular section with its diameter equal to the side of the square, having the same number of turns of wire, and of the same winding length. The factor K is given by the table, as before. The formula for a square section frame or coil is thus:

$$L = 3{\cdot}08 \times 10^{-2} \times \frac{d^2N^2}{l} \times K \quad . \quad (4)$$

where L = the inductance in microhenries.
d = side of square in inches.
N = total number of turns of wire on frame or coil.
l = total length of winding in inches.
K = a number depending on the ratio of d to l, and given in the table on p. 559, Vol. II, of Complete Wireless.

These formulæ apply only to frames and coils with turns closely wound. We shall not treat the cases of spaced windings and rectangular and other shape sections, as these require special treatment, and the appropriate formulæ can always be obtained from special text-books dealing with inductance calculations.

An Example

As an example of the use of (4), consider the case of a loop of side 12 inches wound with 25 turns of wire, occupying a length of half an inch (·5 inch). The ratio of d to l is $\frac{12}{\cdot 5}$, *i.e.*, 24, and from a table of values of K it is seen that K = ·11 when $\frac{d}{l} = 24$. Thus :

$$L = 3{\cdot}08 \times 10^{-2} \times \frac{12 \times 12 \times 25 \times 25}{\cdot 5} \times {\cdot}11,$$

i.e.,

$$L = 3{\cdot}08 \times 10^{-2} \times \frac{144 \times 5 \times 25}{\cdot 1} \times {\cdot}11$$

i.e.,

$$L = 3{\cdot}08 \times 10^{-2} \times 144 \times 5 \times 25 \times 1{\cdot}1$$

or

$$L = 610\ m\text{H (approx.)}.$$

A frame of this value inductance would be of little use for the reception of medium-wave broadcasting stations for, even when tuned with a minimum capacity of 50 m.mfd. (including all the stray capacity of the circuit wiring) the wavelength to which it responds is about 330 metres. A capacity of 150 m.mfd. brings the wavelength up to about 575 metres, and a capacity of 500 m.mfd.—*i.e.*, ·0005 mfd.—tunes the loop to about 1,000 metres. Such a size frame would be most suitable for reception of waves between about 500 and 1,000 metres.

Finding the most Suitable Dimensions of a Frame

This brings us to the problem of finding the dimensions of a frame suitable for a particular purpose. Can we use (3a) and (4) in the reverse direction ? That is to say, can we decide on a value of inductance —*i.e.*, a value for L—and find the number of turns of a particular gauge of wire for any predetermined size and shape of loop ? In the present form, equations (3a) and (4) cannot be used this way. They can be put in a convenient form however.

Consider (3a). We have :

$$L = 2{\cdot}505 \times 10^{-2} \times \frac{d^2N^2}{l} \times K.$$

If, instead of using the total number of turns on the loop, we use the number of turns *per inch*, then :

(No. of turns per inch) × (length of winding in inches)

= (total No. of turns on the loop).

Using n as mathematical shorthand for the number of turns of wire per inch, we have :

$$n \times l = N \quad . \quad . \quad . \quad (5)$$

where l and N are as previously.

Thus, if we employ No. 26 S.W.G. d.s.c. wire, we can wind 48 turns per inch, and 3 inches winding length contains 48 × 3 turns.

i.e., total turns = N = 48 × 3,

i.e., N = 144 turns.

So that in (3a) we may replace N by $n \times l$. Let us do this :

$$L = 2{\cdot}505 \times 10^{-2} \times \frac{d^2(n \times l)^2}{l} \times K,$$

i.e.,

$$L = 2{\cdot}505 \times 10^{-2} \times \frac{d^2n^2l^2}{l} \times K,$$

or

$$L = 2{\cdot}505 \times 10^{-2} \times d^2n^2l \times K \quad . \quad (6)$$

Two Unknown Quantities

In designing our aerial we must first decide on the gauge of wire we shall use, and also on the diameter of the loop (or the side of the square if we are dealing

TABLE I.

s	$\frac{d}{l}$	s	$\frac{d}{l}$
9·6	0·1	0·19	2·5
4·6	0·2	0·14	3·0
2·9	0·3	0·11	3·5
2·1	0·4	0·091	4·0
1·6	0·5	0·076	4·5
1·3	0·6	0·064	5·0
1·1	0·7	0·020	10·0
0·92	0·8	0·010	15·0
0·78	0·9	0·0062	20·0
0·69	1·0	0·0042	25·0
0·60	1·1	0·0030	30·0
0·54	1·2	0·0023	35·0
0·48	1·3	0·0018	40·0
0·44	1·4	0·0014	45·0
0·40	1·5	0·0012	50·0
0·27	2·0	0·00035	100·0

with a square section frame). That is to say, we must fix values for n and d in (6). We are going to wind a frame possessing a certain inductance, hence the value of L is also known, and this leaves l and K unknown. We cannot find K until we know l; but we do not know l—in fact, that is what we are endeavouring to find. Thus we have two unknown quantities in (6) and the problem is apparently insoluble.

By an artifice, however, we can change (6) into a form which overcomes this difficulty. We obtain the following equation :

$$L = 2{\cdot}505 \times 10^{-2} \times d^3n^2 \times S \quad . \quad (7)$$

Where S is a "shape factor," so-called since it depends on the shape of the coil.

Now the value of S can be found from (7), since it is the only unknown quantity in the equation. *To every value of* S *there corresponds one, and only one, value of the ratio* $\frac{d}{l}$. Table I. gives a number of corresponding values of S and $\frac{d}{l}$, and Fig. 4 shows these values graphically, and can be used for finding intermediate values.

In order that values of S and $\frac{d}{l}$ may be read to approximately the same degree of accuracy at all parts of the range of values, the graph has been divided into four parts, (A), (B), (C) and (D), and the scales adjusted accordingly. This could also have been accomplished on one graph by the use of logarithmic scales repeated three times along each axis.

Thus, having found S, $\frac{d}{l}$ is known. Also, d is known, hence l can be found by dividing d by $\frac{d}{l}$, for :

$$d \div \frac{d}{l} = d \times \frac{l}{d},$$

i.e.,

$$d \div \frac{d}{l} = l.$$

Having found l we now know how many turns to wind on our coil or frame, for $N = n \times l$ (see (5)). Note : Since (3a) applies to both coils, of small dimensions, and frames, of larger dimensions, the foregoing process applies to the design of coils as well as to the design of loop aerials. In the case of a frame or coil of square section, the treatment is the same, but the factor $2{\cdot}505 \times 10^{-2}$ is replaced by $3{\cdot}08 \times 10^{-2}$ throughout, and d is then the length of the side of the square in inches, thus :

$$L = 3{\cdot}08 \times 10^{-2} \times d^3n^2 \times S \quad . \quad (8)$$

A Typical Example

Let us apply the process to designing completely a frame which will just tune to 2,000 metres with a ·0005 mfd. variable condenser. The wavelength of 2,000 metres will be reached when the maximum capacity is employed ; as the capacity is reduced the wavelength is decreased. We have first to find what value of inductance is required to tune to this wavelength. We have :

$$\lambda = 1885\sqrt{LC}$$

as the resonance condition of the circuit —see (2)—and λ is to be 2,000 metres when C is ·0005 mfd. Hence :

$$2000 = 1885\sqrt{L \times {\cdot}0005}$$

or

$$\frac{2000}{1885} = \sqrt{L \times {\cdot}0005}.$$

Squaring both sides, in order to dispose of the square root sign, we have :

$$\left(\frac{2000}{1885}\right)^2 = L \times {\cdot}0005,$$

i.e., $L = \dfrac{2000 \times 2000}{1885 \times 1885 \times {\cdot}0005}$

or L = 2250 mH (approx.).

If the minimum capacity of the circuit (including circuit wiring) be taken as 50 m.mfd.—*i.e.*, ·00005 mfd.—the minimum wavelength

TABLE II.

S.W.G. No.	Turns per inch.				
	Enamel.	s.c.c.	d.c.c.	s.s.c.	d.s.c.
18	19	18	17	20	19
20	25	24	22	26	25
22	33	29	26	33	32
24	42	37	31	42	40
26	50	43	36	50	48
28	60	50	40	60	56
30	73	57	45	72	67
32	83	63	50	82	75
34	98	70	55	95	85
36	116	86	64	110	100
38	143	100	71	135	120
40	180	112	78	160	140

to which we can tune is given by (2), and is :

$$\lambda = 1885\sqrt{2250 \times \cdot 00005}$$

or $\lambda = 632$ metres (approx.).

If the minimum capacity be 100 m.mfd., *i.e.*, ·0001 mfd., the minimum wavelength of the circuit can be shown, by the same process, to be 894 metres (approx.).

Turns per Inch

We will suppose that we are going to wind our aerial on a frame of square section of side 15 inches with No. 26 S.W.G. s.s.c. wire. From Table II. we see that we can wind 50 turns per inch with this wire. Thus we have :

$d = 15$ inches
$n = 50$ turns per inch.

Applying (8) we have :

$$2250 = 3{\cdot}08 \times 10^{-2} \times 15 \times 15 \times 15 \times 50 \times 50 \times S$$

from which we see that :

$$S = \frac{2250 \times 10^{-2}}{3{\cdot}08 \times 15 \times 15 \times 15 \times 50 \times 50}$$

or $S = \cdot 009$ (approx.).

From Fig. 4 we see that the value of $\frac{d}{l}$ corresponding to $S = \cdot 009$ is approximately 16. Dividing d by $\frac{d}{l}$ to obtain l we have :

$$l = \frac{15}{16},$$

i.e., $l = \cdot 94$ inches (approx.).

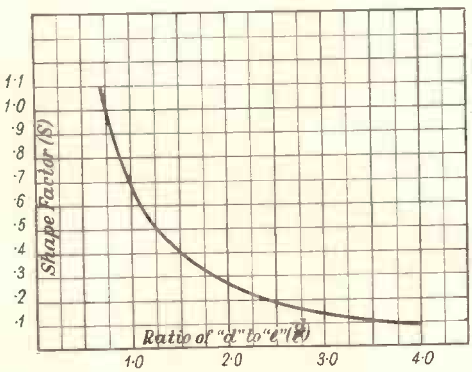


Fig. 4B.—Graph showing Corresponding Values of S (Shape Factor) and $\frac{d}{l}$.

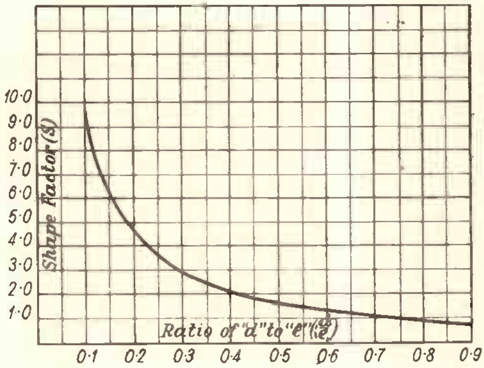


Fig. 4A.—Graph showing Corresponding Values of S (Shape Factor) and $\frac{d}{l}$.

Summary of Data obtained

Hence the total number of turns on the frame will be ·94 × 50, *i.e.*, 47 turns. The data for our frame may then be summarised thus :

Section	= square.
Side (d)	= 15 inches.
Wire	= No. 26 S.W.G., s.s.c.
Total turns (N)	= 47
Winding length (l)	= ·94 inches.
Inductance (L)	= 2250 mH.
Max. wavelength with ·0005 mfd. capacity tuning condenser	= 2000 metres.
Min. wavelength with 50 m.mfd. capacity	= 632 metres.
Min. wavelength with 100 m.mfd. capacity	= 894 metres.

Other Points to observe in Designing a Frame Aerial

There are certain other points which should be observed in designing a frame aerial. A simple experiment with a number of frames will show that the larger the frame, within reasonable limits, the greater the induced signal voltage, hence it is advisable to employ a frame of as large dimensions as possible consistent with mechanical stability.

Vibration

If the aerial is wound on a skeleton frame, *i.e.*, no actual sides to the frame, the corners and supporting cross-pieces holding the wire in position so that the

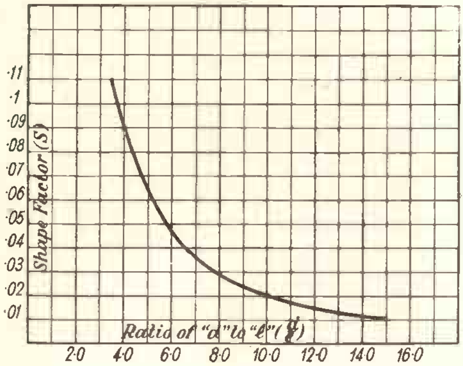


Fig. 4C.—GRAPH SHOWING CORRESPONDING VALUES OF S (SHAPE FACTOR) AND $\frac{d}{l}$.

wire can vibrate, then great care must be taken to see that the amount of vibration is reduced to a minimum. Vibration of the wires causes a small change in inductance, with a consequent small change in tuning. The following equation gives the change in tuning caused by a small change in inductance. We have :

$$\Delta n = \frac{1}{2}\frac{\Delta L}{L}n \quad . \quad . \quad . \quad . \quad (9)$$

The symbol Δ is pronounced " delta " and means " the small change in . . ." Thus Δn means " the small change in n," and ΔL is " the small change in L." The Δ cannot be separated from the n or the L, which *immediately* follows it, and Δ on its own means nothing intelligible. The term L in the denominator of the fraction on the right-hand side is the actual inductance before the slight change—due to vibration—occurs, and n is the frequency of the incoming signal, or the frequency to which the circuit is tuned before the change in inductance occurs.

Suppose that we are using a frame of inductance 200 *m*H. tuned to a wavelength of 300 metres (frequency $= 10^6$ cycles per second). If the vibration is sufficient to cause a change of one part in a thousand in the inductance, *i.e.*, ΔL is one-thousandth part of 200 *m*H., and hence $\frac{\Delta L}{L} = \frac{1}{1000}$, then we have :

$$\Delta n = \frac{1}{2} \times \frac{1}{1000} \times 10^6,$$

i.e., $\Delta n = 500$ cycles per second.

In other words, the tuning changes by an amount of 500 cycles per second. This amount is scarcely sufficient to lose a station, except in the case of a very highly selective receiver such as a stenode radiostat instrument, but would introduce distortion of the modulation. At a wavelength of 1,500 metres (frequency = 200 kc/s.) the frequency change due to a change of one part in a thousand in inductance is :

$$\Delta n = \frac{1}{2} \times \frac{1}{1000} \times 200{,}000,$$

i.e., $\Delta n = 100$ cycles per second.

This change is almost negligible, and the sideband distortion thereby introduced would be practically undetected.

Effect of Winding Length on Minimum Positions

It can also be shown, by experiment and mathematically, that when the winding length of a frame aerial is too great the minimum positions of the frame are ill-defined. For ordinary broadcast reception this is not highly important, although a well-defined minimum is useful on occasions for differentiating between two signals very close in wavelength. A definite minimum is of great importance in the case of frames used for direction-finding work in connection with marine and air navigation.

Short-wave Reception on Frame Aerials

The case of short-wave reception on loop aerials requires special consideration. The inductance required for a short-wave tuning circuit is of the order of 1 to 10 or 15 *m*H., and hence the dimensions of the frame cannot exceed certain limits, since a large frame will possess too much inductance for the circuit. It will also be shown that the rigidity of the frame, *i.e.*, its freedom from inductance variation due to mechanical vibration, must be much greater than that required for medium-wave and long-wave frames.

Calculating Inductance of Short-wave Frames

The inductance of short-wave frames can be calculated by means of the formulæ we have already employed for medium-and long-wave frames, but the inductance values so obtained are only approximate, This is because :—

(1) The frequencies of the signals received on the frame are so high that the inductance formulæ are approximate only.

(2) The presence of the materials used for the frame structure causes energy losses with a decrease of inductance. In the case of medium- and long-wave frames these effects are quite small in comparison.

(3) Very few turns of wire are used, and the wire is of heavy gauge and usually spaced, hence a correction to the formulæ is necessary to account for the spacing.

The inductance values calculated with the foregoing formulæ are sufficiently accurate, however, for all ordinary experimental work. Indeed, the only way to obtain more accurate values is to measure under actual working conditions, as there is no formula which takes account of all these effects.

A Useful Table

The following table, which is reproduced by permission of the Editor of *World-Radio*, gives approximate wavelength ranges for various sizes of short-wave loops of square and circular section, wound with No. 18 S.W.G. bare copper wire. The use of a heavier gauge wire results in smaller inductance values, and hence the wave

Type.	No. of Turns.	d = 12 ins.		d = 18 ins.		d = 36 ins.	
		λ min.	λ max.	λ min.	λ max.	λ min.	λ max.
Circular Loop (diam. = *d*)	1	6	*9·5	10	23	13	33
	2	11	27	13	33	18	46
	3	13	33	16	42	23	59
Square Loop (side = *d*)	1	6·5	†10	11	27	15	38
	2	13	31	15	38	20	53
	3	15	38	18	47	25	66

* Assuming a maximum tuning capacity of 25 m. mfd. ; all other figures are for a maximum capacity of ·0001 mfd.

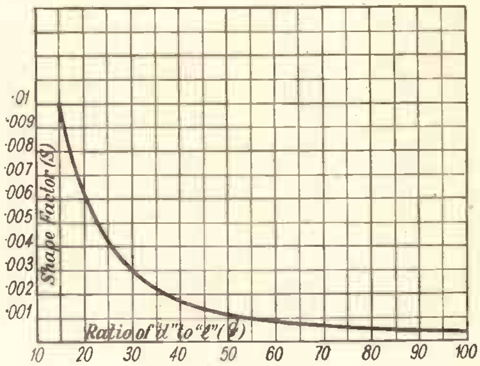


FIG. 4D.—GRAPH SHOWING CORRESPONDING VALUES OF S (SHAPE FACTOR) AND $\frac{d}{l}$.

ranges are displaced, both maximum and minimum wavelengths being shorter than with the gauge 18 wire. The maximum and minimum wavelength figures can be displaced by several metres due to stray capacitive and inductive effects in the circuit with which the aerials are used.

Stability of Tuning

Let us examine the stability of tuning of a short-wave loop by means of (9). For an inductance variation of one part in a thousand at a wavelength of 30 metres (frequency = 10^7 cycles per sec.) we have :

$$\Delta n = \tfrac{1}{2} \times \frac{1}{1000} \times 10^7,$$

i.e., $\Delta n = 5$ kc/s.

This change is sufficient completely to lose a station. At a wavelength of 15 metres a similar inductance variation produces a frequency change of 10 kc/s.

If we limit the frequency variation of the tuning circuit to 500 cycles per second at 30 metres, then we have :

$$\Delta n = 500$$

and so $$500 = \tfrac{1}{2} \times \frac{\Delta L}{L} \times 10^7,$$

i.e., $$\frac{\Delta L}{L} = \frac{1000}{10^7},$$

or $$\frac{\Delta L}{L} = \frac{1}{10000}.$$

In other words, the frame must be so rigid, mechanically, that vibration does not cause a change in inductance greater than one part in ten thousand.

ACOUSTICAL ENERGY AND WATTS

By F. W. LANCHESTER, LL.D., F.R.S., Etc.

The Nature of a Sound Wave

As a prelude to entering on the discussion of the dynamics of sound propagation and radiation, it is desirable to devote some consideration to the nature of a sound wave in free air.

In a sound wave the movement of the air particles has often been likened to the oscillation of a pendulum, and this analogy has been pushed to the extent of suggesting that in the sound wave there are alternations of potential and kinetic energy of the same kind. This is only true to a very limited extent; in the case of a reflected wave, sometimes termed the *stationary wave*, we have definitely nodes and loops, and the energy actually alternates between potential and kinetic, in other words, pressure and motion.

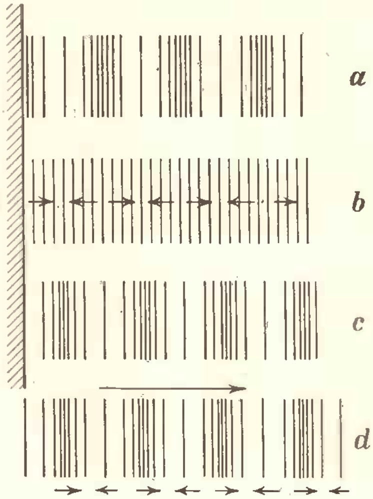


Fig. 1.—Diagram showing how Energy actually alternates between Potential and Kinetic.

Energy in the Form of Pressure

This is illustrated in Fig. 1*a* and *b*; in *a* the *energy is in the form of pressure*, that is to say, contained in the compression of the air in the regions indicated by the crowding together of the vertical lines (which represent strata of air).

One quarter phase (90°) later, in Fig. 1*b* the energy is kinetic, namely, in the form of motion as indicated by the arrows. *S* is the reflecting surface, but the *stationary wave* may be regarded also as two plane wave trains travelling in opposite directions and superposed.

An Important Fact

This calls attention to a very important fact. Since in the stationary wave the *same energy* appears alternately as potential and kinetic, in the two superposed waves forming the stationary wave the kinetic and potential energies are equal to one another. This fact, which is supported by a more general theorem, will be made use of later.

The Plane Wave in Free Air

The plane wave in free air differs fundamentally from the reflected or stationary wave; *it carries energy with it.* A corollary of this is that where the pressure is maximum the air particles move in the same direction as the wave, and where the pressure is least in the opposite direction.

We do not consider a single wave, but a train or succession of equal and similar waves, and for the time being we postulate that the wave front is flat and the propagation is rectilinear.

Now, under these conditions, assuming that, in accordance with the usual convention, we are dealing with a simple or pure tone, *i.e.*, a tone of one frequency only, the rise and fall of pressure, as it would be recorded by a stationary observer, will follow the *sine law* (harmonic in form) and the velocity of the air, or movement of the air particles, follows the same law and the two are so phased that the maximum pressure coincides with the maximum forward velocity and minimum pressure with maximum backward or retrograde

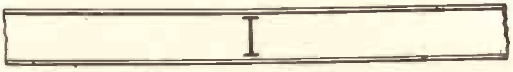


Fig. 2.—CONVENIENT METHOD OF STUDYING THE ACT OF PRODUCING A SOUND.

Showing the diaphram as being in the middle of a straight pipe.

Fig. 3.—CONVENIENT METHOD OF STUDYING THE ACT OF PRODUCING A SOUND.

Here the diaphragm is shown as being at one end of the pipe.

velocity. That is the *régime* which obtains for the sound wave in free air.

Best Method of Studying the Act of Producing a Sound

Now the act of producing a sound wave or train of waves may be best studied by considering the sound as passing along a straight pipe, and at some point supplying a diaphragm parallel to the wave front to which motions and forces are applied by electrical or mechanical means in exact imitation of the forces which the air would be transmitting were the diaphragm not there.

Fig. 4. — DIAGRAMMATIC REPRESENTATION OF CONE TYPE SPEAKER.

A Difficulty

There is one difficulty in this conception ; since the diaphragm is doing work on one part of the air column previously done by the other part, the part which the diaphragm replaces has to be disposed of. If we could have a vacuum on one side of the diaphragm this would be easy, but no such solution is possible. If we ignore the difficulty and (Fig. 2) examine the consequence we find that the diaphragm will have to emit in both directions ; considerations of symmetry alone tell us that this must be so, and twice the forces will have to be supplied that would be otherwise necessary, but that is all ; we have two speakers instead of one.

Another Solution

Another solution is illustrated in Fig. 3 ; here the diaphragm is arranged at the end of the tube, this disposition results in relieving a great part of the " load " on the side of the diaphragm open to the air.

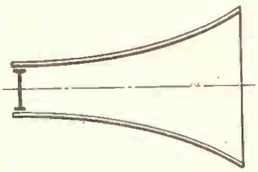


Fig. 5.—HERE THE FLARE ON A SIDE OF THE DIAPHRAGM RESULTS IN GREATER ENERGY EMISSION ON THAT SIDE.

In every case the diaphragm is shown as a piston so that the air column is dealt with uniformly over the whole area.

TYPES OF LOUD SPEAKER

The conceptions embodied in Figs. 2 and 3 give rise to two distinct types of speaker. Although by way of approach we have considered the sound as restricted to a pipe or tube this has to be abandoned or modified when we consider the real problem.

Horn or Flare

To begin with, the pipe obviously cannot go on for ever, nor can it be just cut off at the end ; if the latter there would be a powerful resonant frequency like an organ pipe of similar length. The solution is the well-known horn or flare. The flare may begin right away at the diaphragm or it may be preceded by a short length of " acoustic tube." The extreme flare is the baffle board ; Fig. 4 represents diagrammatically the cone type of speaker, which radiates sound from both sides of the diaphragm just as in Fig. 2 ; but the pipe has been replaced by a flat baffle.

Fig. 5 is a modification in which the *régime* more nearly resembles that of Fig. 3 ; the flare on one side of the diaphragm results in greater energy emission on that side. Fig. 6 is a type more wholeheartedly in accordance with Fig. 3, the diaphragm is of larger diameter than the throat of the flare, which now becomes a real horn.

Fig. 7 shows a type in which the pipe or tube is retained as a prelude to the flare, this is the Lanchester acoustic tube

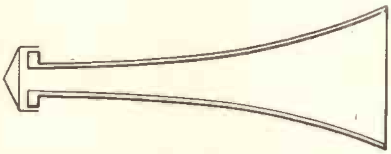


Fig. 6.—THE DIAPHRAGM IS HERE OF A LARGER DIAMETER THAN THE THROAT OF THE FLARE, WHICH NOW BECOMES A REAL HORN.

type in which the length of the tube is made approximately one-quarter of the wave-length of the lowest tone it is required to emit.

Principle the same in all Cases

But the principle is the same in all cases, and the work to be performed by the diaphragm is in every case determined by the energy per second or watts required to feed or maintain the acoustic emission.

Pressure and Velocity related to Amplitude and Frequency

We assume a simple tone of amplitude a and frequency f. In a simple tone the motion of the air particles as the wave is transmitted is *harmonic*, and as such may be represented as one component of uniform circular motion.

a = amplitude in inch units.
f = frequency, cycles per second.

The maximum velocity is determined simply as equal to a particle moving in a circular orbit diameter = a with frequency or " revolution speed " = f, and is therefore given by the expression—

$$\pi af \text{ inches per sec. or } \frac{\pi af}{12} \text{ ft. sec.} \quad . \quad (1)$$

The Air Pressure

We have next to determine the air pressure, *plus* or *minus*, atmospheric pressure being datum. This is the maximum pressure difference caused by the wave in its passage and is simultaneous with the maximum velocity *plus* or *minus*. Our first step is to find an expression for the energy per cu. ft. of any region filled uniformly with sound waves of amplitude a and frequency f. We substitute a circular orbit of constant velocity for the harmonic motion as might be conceived to arise from two trains of waves at right angles. We know that this will give a value twice that sought for.

The mass of 1 cu. ft. air at 20° C. is ·075 lb. Energy $\frac{m \times V^2}{2g}$ or per cu. ft. air

$$\frac{\cdot 075 \times \pi^2(af)^2}{64\cdot 4 \times 144} = \cdot 00008\ (af)^2 \text{ ft. lbs.}$$

To reduce this from circular motion to simple harmonic motion we divide by 2, giving ·00004 $(af)^2$ ft. lbs. per cu. ft.

Finding the Relation between Energy and Pressure

The above is the energy of motion, or kinetic component of the total energy; we now have to find the relation between energy and pressure. Our method will be analogous to the above; we take the maximum pressure difference as applying to the whole region (1 cu. ft.) and we divide this by 2 for the real value. This is precisely what we do when we convert from vector to R.M.S. values in electrical problems. Let p be the maximum or vector pressure (pounds per square inch). We take 1 cu. ft. (literally a foot cube) as subject to pressure p; then, p being small compared to atmospheric pressure, the linear compression will be $\frac{p}{14\cdot 7\gamma}$ (where gamma is the usual thermodynamic constant) = $\frac{p}{20\cdot 6}$, and pressure on one square foot face $144p$ or work done in compression is :

$$\frac{144p^2}{20\cdot 6 \times 2} = 3\cdot 5p^2,$$

and the " R.M.S. value " is half this, $= 1\cdot 75\,p^2$.

It has already been pointed out that the kinetic energy and the potential energy are equal, hence :

$$1\cdot 75p^2 = \cdot 00004\,(af)^2$$

or, $$p^2 = \cdot 0000228\ (af)^2$$

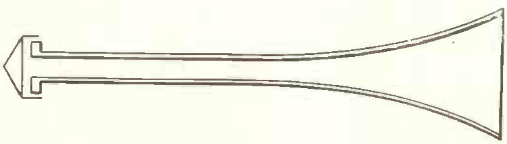


Fig. 7.—THIS SHOWS A TYPE IN WHICH THE PIPE OR TUBE IS RETAINED AS A PRELUDE TO THE FLARE.

or, $$p = \cdot 00475\ af = \frac{af}{210}$$

pounds per sq. in.

This expression gives us at once the pressure vector, namely, the maximum or minimum (above or below atmosphere) if we know the value of *amplitude* × *frequency*.

Watts per Square Foot of Wave Front

From the foregoing the total energy per cu. ft. is given by the expression :

$$\cdot 00004(af)^2 \times 2 \text{ ft. lbs.}$$
$$= \cdot 00008\ (af)^2 \text{ ft. lbs.}$$

Now the power in foot pounds per second passing through a " window " 1 sq. ft. area will be the energy per cu. ft. multiplied by the velocity of sound, namely :

$$\cdot 00008\ (af)^2 \times 1144 = \cdot 092(af)^2 \text{ ft. lbs./sec.}$$

Since 746 watts = 550 ft. lbs. sec. (= 1 h.p.) ;

$$\text{watts per sq. ft.} = \frac{746}{550} \times \cdot 092\ (af)^2$$
$$= 0 \cdot 125\ (af)^2,$$

or, $(af)^2$ = watts per sq. ft. × 8.

What these Expressions give Us

The expressions deduced above give us in convenient units the relations between *amplitude* × *frequency* and the pressure and velocity values, also the energy density of the acoustic emission, that is, the power or watts radiated, or carried by the sound beam per square foot area.

It is to be observed that we do not have to consider the amplitude and frequency separately, the product of the two alone affects our calculations. We find in these expressions everything we need, whether it be for investigating the electrically operated speaker or the mechanically operated gramophone.

HOW TO ELIMINATE INTERFERENCE DUE TO A NOISY MOTOR OR GENERATOR

THE elimination of static interference from adjacent electric motors, which takes the form of intermittent crackling noises, rests with the users of these.

Interference from an electric motor may be cured by earthing the centre of two condensers connected in series across the motor brushes. The condensers should each be of about 2 microfarads capacity and should be capable of withstanding at least twice the working voltage of the motor.

Fitting the Silencing Devices

The silencing devices should be fitted as close as possible to the machine with very short leads and also with a short, heavy earth-lead. It is interesting to know that adjustment of brush position can also help to reduce interference.

Interference from Generators

Generators produce both high-frequency and low-frequency interference. In the case of small machines the interference is generally of the high-frequency type and is amenable to the same treatment as for motors.

Real low-frequency interference is experienced due to ripple on large supply machines, and is usually only experienced on mains-operated sets where the cure is improved smoothing and efficient earthing of the chassis of the set.

USING VARIABLE-MU VALVES

By FRANK PRESTON, F.R.A.

We will start by seeing what modifications should be made to a set originally designed for use with an ordinary S.G. valve to make it suitable for a valve of the V.-M. type.

At this juncture it should be made quite clear that it is not *essential* to make any alteration at all because any screened-grid valve can be replaced by a variable-mu one of corresponding type with every satisfaction. The degree of amplification will be practically unchanged, but the new valve will cause less distortion though it cannot be employed as a volume control.

Modifying a Previous Screened-Grid Stage

Four different ways of modifying the previous S.G. stage are shown in Fig. 1. At (*a*) the wire previously used to join the lower end of the aerial coil to H.T. negative has been transferred to the slider of a potentiometer connected across the grid bias battery; a ·1 mfd. non-inductive fixed condenser has also been joined between the coil and H.T. negative to by-pass high-frequency currents. This method is quite satisfactory when the grid bias battery is kept outside the set and its positive terminal is joined directly to high-tension or low-tension negative. If the positive G.B. terminal were joined to the point marked A this method would be unsuitable because, even when the set were switched off, the battery would be in parallel with the potentiometer winding and would therefore quickly be exhausted.

In the latter case, illustrated at (*b*) in Fig. 1, it would be necessary to alter the potentiometer connections as shown.

The system of connections shown at (*c*) is often employed to isolate the potentiometer from the G.B. battery when the set is not in use. In this case a switch (marked S 2) is combined with the potentiometer so that when the latter reaches the end of its travel the switch contacts are broken. A special potentiometer for this purpose is described in the article entitled "Potentiometers."

Fig. 1 (*d*) shows the connections used where a band-pass filter is employed for aerial tuning. In this case the by-pass resistance normally connected from the lower end of the coils to H.T. negative is joined to the slider of the potentiometer. The latter may be connected in any of the ways shown at (*a*), (*b*) and (*c*).

De-coupling

In the latter case the by-pass resistance serves also to de-couple the grid circuit of the V.-M. valve and thus there will be no likelihood of interaction being caused by

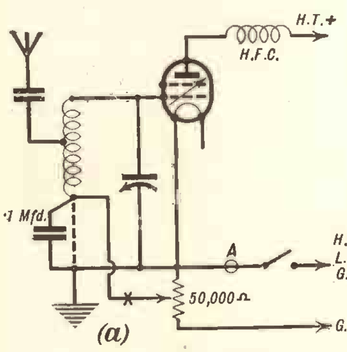


Fig. 1A.—Different Methods of supplying Grid Bias to Variable-Mu Valves.

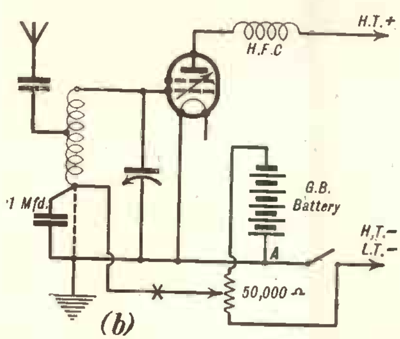


Fig. 1B.—Showing the Potentiometer Connection altered.

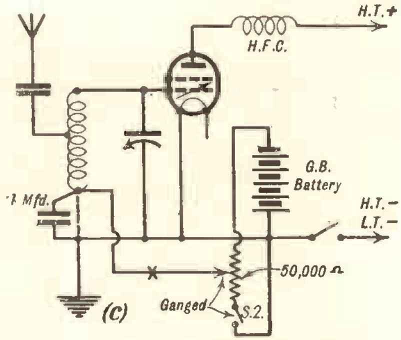


Fig. 1c.—Isolating the Potentiometer from the Grid Bias Battery when the Set is not in Use.

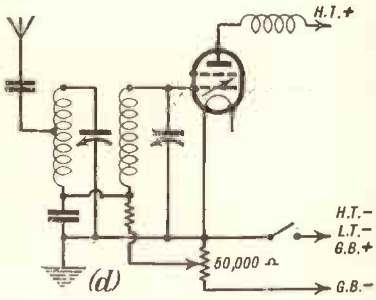


Fig. 1d.—Connections used where a Band-pass Filter is employed for Aerial Tuning.

using the same grid bias battery for both L.F. and V.-M. valves (the same battery is almost invariably used in practice). But with the connections shown in the other three circuits feed-back might occur under some circumstances. This could be prevented by inserting non-inductive resistances of from 1,000 to 100,000 ohms in the potentiometer leads at the points marked with a cross.

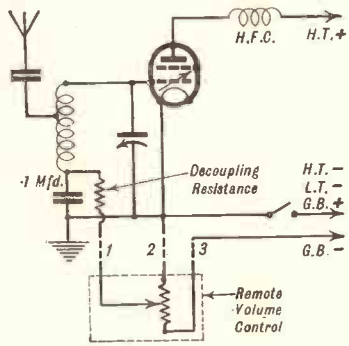


Fig. 2.—Method of obtaining Remote Volume Control with a Variable-Mu Valve.

Remote Control

When such de-coupling is provided the potentiometer can, if desired, be removed from the set and installed at some distant point to give remote control of volume. Naturally, it must be connected to the set by the three wires marked "1," "2," and "3" in Fig. 2. Remote control is very convenient when a speaker is used in a room different to that in which the set is situated and is something of a refinement.

Two V.-M. Stages

The connections required for a set having two V.-M. stages are shown in Fig. 3. In this case de-coupling resistances are essential to prevent feed-back between the two valves. Here again the potentiometer may be connected in any of the ways shown in Fig. 1. depending upon the connections used for the G.B. battery. It was mentioned before that less de-coupling is required for V.-M. valves, and the usual values of resistances and condensers are indicated in Fig. 3. All

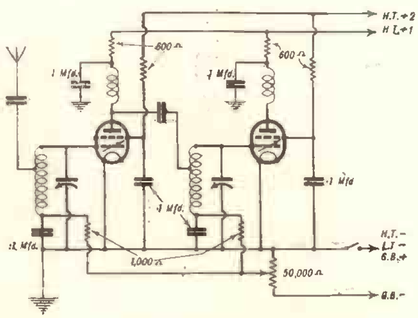


Fig. 3.—Circuit of a Two-stage Variable-Mu Amplifier.

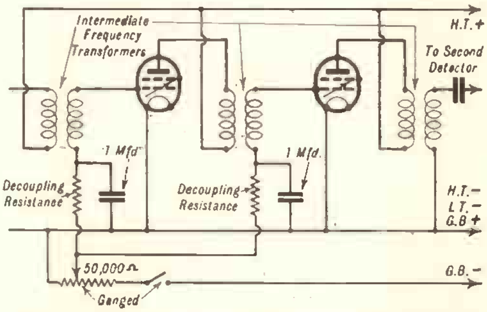


Fig. 4.—Showing how Variable-Mu Valves are used in the Intermediate Frequency Amplifier of a Superheterodyne.

four condensers of ·1 mfd. should be non-inductive.

For Superheterodynes.

Variable-mu valves are particularly useful in the intermediate-frequency stages of a superheterodyne; their freedom from the troubles of cross modulation and beat interference render them almost invaluable for this purpose. The advent of this type of valve will probably contribute in a very large measure to the future popularity of the superheterodyne which has in the past suffered very considerably from the results of cross-modulation.

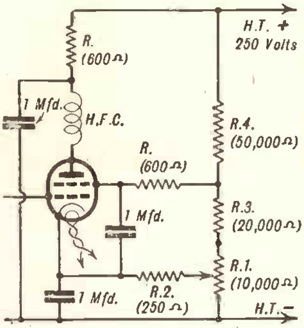


Fig. 5.—This Diagram shows the Values of Feed Resistances required for a single Cossor M.V.S.G Valve.

The skeleton circuit of Fig. 4 shows the connections required for the I.F. amplifier. The de-coupling resistances shown can have any value from about 2,000 ohms upwards; they should be non-inductive, as should also the ·1 mfd. by-pass condensers.

Grid Bias Voltage

When a single variable-mu stage is employed a 9-volt grid bias battery is generally sufficient to give the necessary control of volume, but in extreme cases where the set is installed very near to a powerful station a 15-volt battery might be required to prevent overloading of the detector valve. If two stages are used a 15-volt battery will nearly always be required. The potentiometer may be of any good type having a resistance of from 20,000 ohms to 50,000 ohms; the latter value is generally chosen, since it imposes a smaller load on the G.B. battery.

V.-M. Valves for A.C. Sets

Up to now we have confined our attention to battery valves, but the same general principles apply to those of the indirectly-heated A.C. type. The only real difference is that for the latter valves, grid bias is provided by suitable "dropping" resistances instead of by a battery. Fig. 5 shows the circuit arrangement of a single V.-M. stage for an all-A.C. set; the correct values for resistances R.1 to R.4 depend upon the particular valve in use, whilst the two resistances marked R. may have any value above about 500 ohms. The resistance values actually shown refer to the Cossor MVSG, but they would be different for any other valve. It is impossible to state here the correct values for every make and type of valve, but in any case, they are given on the makers' instruction sheets.

Constant Screening Grid Voltage Essential.

The reason why the various resistances must be of a fairly critical value is that the voltage applied to the screening grid must remain absolutely constant, otherwise the valve will distort. There is no difficulty in fulfilling this requirement when high-tension and grid bias supplies are obtained from batteries, but in a mains set the bias voltage is actually taken away from the high-tension voltage. In consequence, it would appear that the screening grid voltage must vary as the G.B. voltage is altered. Without entering into (fairly advanced) mathematics, I must ask you to take my word for it that the screening grid voltage *can* be maintained at a uniform level by suitably proportioning the values of resistances R.1 to R.4.

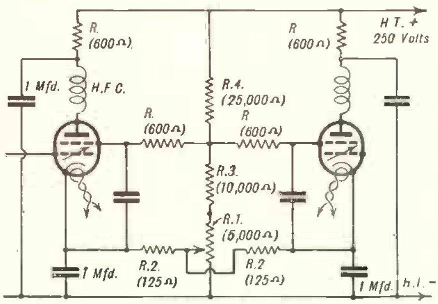


Fig. 6.—The Values of Feed Resistances required for a Two-stage Amplifier using Cossor M.V.S.G. Valves.

Tuning circuits are omitted for simplicity.

When two indirectly-heated V.-M. valves are used a single potentiometer will control both, but the values of the various feed resistances are different to those required for a single stage. As an example of this, Fig. 6 is given to show the resistances required for two Cossor MVSG valves; compare these with those shown in Fig. 5.

Providing Automatic Volume Control

Although the use of the variable-mu valve to provide automatic volume control has not yet been fully exploited, it has found very great favour with American designers who have incorporated it in nearly all their latest sets.

A large number of automatic volume control circuit arrangements have been devised, but they all depend upon the fundamental principle that the bias voltage applied to the variable-mu valves (both H.F. and Intermediate-Frequency in the case of superheterodyne) is increased or decreased simultaneously with an increase or reduction of signal voltage applied to the detector valve.

In some cases the bias control is effected by the detector valve itself, in others a separate A.V.C. (automatic volume control) valve is connected in the grid circuit of the detector, whilst again in other instances special valves of the diode and duo-diode class have been evolved to fulfil the purpose. A fairly typical circuit is given in Fig. 7.

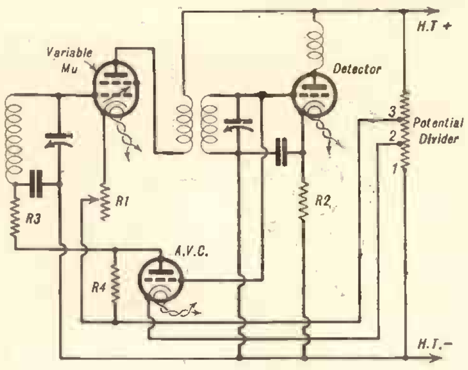


Fig. 7.—A TYPICAL AUTOMATIC VOLUME CONTROL CIRCUIT.
A separate control valve (A.V.C.) is used.

Using a Separate Valve

In this arrangement a separate A.V.C. valve is employed, and the function of the circuit is briefly as follows: When the V.-M. valve receives no signal input its grid bias is at a minimum, being, in fact, that developed across the variable resistance R.1. The anode bend detector receives its negative grid bias in the normal manner by the voltage drop across resistance R.2. The A.V.C. valve is also biassed to the point at which it will pass no anode current by the voltage between points 1 and 2 on the potential divider in parallel with the H.T. supply. Since the grid of the V.-M. valve is connected to the H.T. supply through the de-coupling resistance R.3, and the automatic control bias resistance R.4, it is different in potential to its cathode only by the voltage across R.1 when no current is passing through R.4.

But when a strong signal is applied to the detector the same signal actuates the A.V.C. valve, which then also operates as an anode bend detector. Under these conditions a current flows through R.4 and, hence, a voltage drop occurs across it. This latter is applied through R.3 in the form of additional bias to the V.-M. valve, As a result the amplification of the latter valve is reduced by an amount proportional to the signal voltage on the grid of the detector (and hence the A.V.C.) valve.

By first setting R.1 any desired volume level can be maintained on every transmission. R.1 can also be used as a manual volume control.

A Disadvantage

At first sight it would appear that automatic volume control offers such wonderful advantages that it should be made a feature of every future set. But its blessings are rather mixed, because, although it does provide a uniform volume level of reproduction, it tends to give emphasis to background noises, static, etc., under some conditions. For instance, when operating the tuning dial the "mush" which appears between stations is amplified to the maximum degree by the variable-mu valves, and, in consequence, is liable to approach objectionable limits. In the same way a signal which is subject to fading is reproduced at constant strength but background noises become louder as the signal fades.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

BATTERY CHARGING METHODS

HIS MASTER'S VOICE AUTOMATIC RECORD CHANGERS

WIRELESS THEORY MADE PLAIN

1/-

Part 21

IN 32 WEEKLY PARTS

PART 21.

BATTERY CHARGING METHODS

By H. E. J. BUTLER

BATTERY charging has become an essential part of a wireless retail business, because although electric light mains are now generally available, it is evident that battery sets are still in great demand.

The Business Side

However large or small a battery charging business may be, it is necessary to adopt a system which will enable customers' cells to be easily distinguished. This is all the more important now that a large number of the same size and make of cells are in use. The best method to adopt depends on the volume of trade. Where only a small amount of charging is done, the simplest method is to secure a label, bearing the customer's name, under one of the terminals, on receipt of the accumulator. Do not use tie-on labels, because these are more likely to be lost. When a large battery charging business is carried on, more precautions are necessary. A book of printed and numbered receipts is used to give the owner a satisfactory claim to his battery when he returns for it. The number of the receipt and the customer's name are put on the label, which is secured under one of the battery terminals. A carbon copy of the receipts should be kept to give a record of the business done within a specified time.

Lending Cells

The policy of lending cells, free of cost, whilst a customer's battery is being charged, is a scheme to be avoided except at a time when business requires a good deal of encouragement.

Costing

The running costs of a charging station include electric power, distilled water and acid. The cost of current is, of course, by far the largest item. In order to separate the power cost when the same supply is used for other purposes, it is necessary to instal a check meter in the power supply circuit of the charging plant. Most supply companies will fix a meter for this purpose at a small rental, and one may prefer to have the company's account rendered separately.

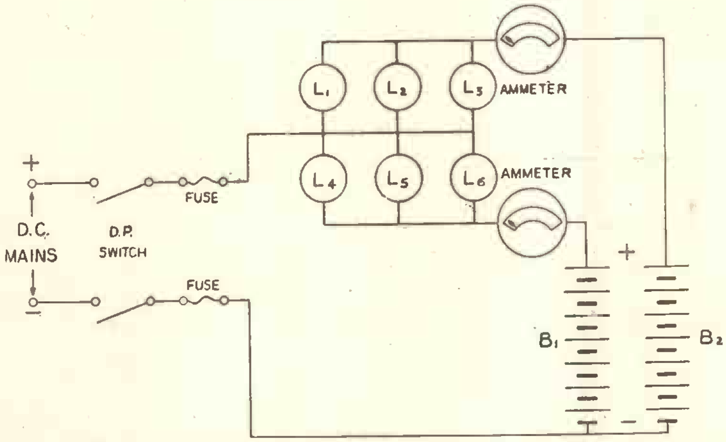


Fig. 1.—THE CIRCUIT USED FOR CHARGING BATTERIES FROM D.C. MAINS WHEN THE TOTAL VOLTAGE OF THE CELLS EXCEEDS THE MAINS VOLTAGE.

This circuit is also used when it is necessary to charge two banks of cells at different rates.

Accessories Required

The principal accessories required are distilled water and dilute sulphuric acid. For wireless accumulators the acid strength is usually 1,250 specific gravity. This acid will be required for refilling neglected or old cells with fresh electrolyte. A smaller quantity of 1,280 and 1,300 strengths as well as pure (1,840) acid may be stocked for adjusting the specific gravity of battery acid. The other accessories required include an unbreakable rubber composition funnel, rubber tape, 5 millimetres cab-tyre sheathed connecting wire and lead-coated spade terminals for making connections to the batteries. A hydrometer is essential. It is advisable to have one of the unbreakable types, which permit a small quantity of acid to be drawn from the cell by means of a rubber bulb. A cell-testing voltmeter for making cadmium tests is not essential unless car batteries are also to be dealt with.

Methods of Charging

The kind of charging plant required depends on the nature of the power supply available. If D.C. mains are to be used, no special plant is required, under ordinary circumstances. For charging from A.C. supplies, the initial outlay is greater, although the working cost is less than for a D.C. plant. Where no electric mains are available, it is necessary to have a generating set.

CHARGING FROM D.C. SUPPLIES

When a D.C. supply is available, the simplest method of charging accumulators is to connect the batteries to the mains, in series with a lamp resistance and an ammeter. The lamp resistance consists of two or more lamps connected in series or parallel, according to the charging current required. Although a wire-wound resistance may be used for regulating the current, lamp resistances are the most convenient, on account of the ease and certainty with which the current can be regulated.

Maximum Number of Cells

The maximum number of 2-volt cells which can be charged at a time, in series, is limited by the voltage of the supply mains. This number is found by dividing the mains voltage by 2·7. Thus, on a 100-volt supply the maximum number of cells which can be charged in series is thirty-seven ; although the nominal voltage of a battery of thirty-seven cells is 74 volts. When it is necessary to charge more than the maximum number of cells at one time, this is done by arranging the cells in series—parallel banks as shown in Fig. 1.

For the Greatest Efficiency

In order to effect the greatest economy when charging through lamp resistances, always connect as many cells as possible in series. For example, suppose two cells are charged at 1 ampere for twenty hours from a 200-volt main. The number of units used would be four. If, instead of two cells, twenty cells were connected in series and charged at the same current for the same length of time, the power consumption would still be four units.

Cost of Charging from D.C.

Irrespective of the number of cells charged at the same time the cost of charging a batch of accumulators is found as follows :—

$$\text{Cost (pence)} = \frac{V \times I \times t \times d}{1{,}000}.$$

Where V is the mains voltage,
I, the total current in amperes,
t, the duration of charge in hours, and
d is the price of 1 unit, in pence.

How to Connect the Cells

Fig. 2 shows the fundamental circuit principle used when charging batteries from D.C. mains, L_1, L_2, L_3 and L_4 represent four standard large bayonet cap bulb holders, which are connected in parallel. One pole of the bulb holders is connected to the positive main, while the other common wire of the holders is connected to the positive terminal of the cell or bank of cells to be charged. An ammeter is connected in the circuit as shown, to indicate the value of the charging current. The cells are themselves connected in series ; that is to say, the positive terminal of one cell is connected to the negative of the next, and so on, as indicated in Fig. 2.

The Number of Lamps

The number of lamps required to pass a specified charging current depends on the size of the lamps, voltage of the mains, and the voltage of the battery. It is not easy to arrive at this by simple calculation, unless the number of cells on charge is few. With the aid of the ammeter it is a very simple matter of trial to adjust the charging current to the required value by inserting the lamps one at a time in the holders. A table is given on p. 986 to enable the estimation of the maximum number of lamps likely to be required, and to serve as a guide to the maximum current passed by different lamps.

Cells of Various Capacities

Since it is most economical to wire as many cells as possible in series, it is usually necessary to connect up cells of various capacities in series. When this is done it is essential to limit the charging current to that of the smallest cells in circuit, because the charging current of any cell must never be exceeded. The larger cells in the circuit will suffer no harm through the low rate of charge. The smallest cells will be charged before the larger ones, so that it is necessary to remove them from the circuit and continue charging the larger cells, if desired, at the higher rate now possible.

A Practical Example

Consider a practical example of this arrangement. A number of 20 ampere-hour capacity wireless cells, requiring a maximum charging current of ½ ampere, are to be charged in series with several 45 ampere-hour cells requiring a maximum current of 1 ampere. The cells are placed on charge at ½ ampere until the 20 ampere-hour cells are finished. These cells are then taken out of circuit. The 45 ampere-hour cells are then charged alone at 1 ampere until they are fully charged. When the smaller cells are taken out the larger cells are about half charged.

Charging H.T. Accumulators

For charging high-tension accumulators the same circuit principle is evolved, except that it is sometimes necessary to wire two lamps in series in order to obtain enough resistance to limit the current. Instead of using an ammeter in the circuit a milliammeter is used. An instrument reading 0–500 milliamperes will be most convenient. Since the requirements of high-tension battery charging are different from those of low-tension battery charging, it is advisable to have these two circuits arranged independently on the charging board.

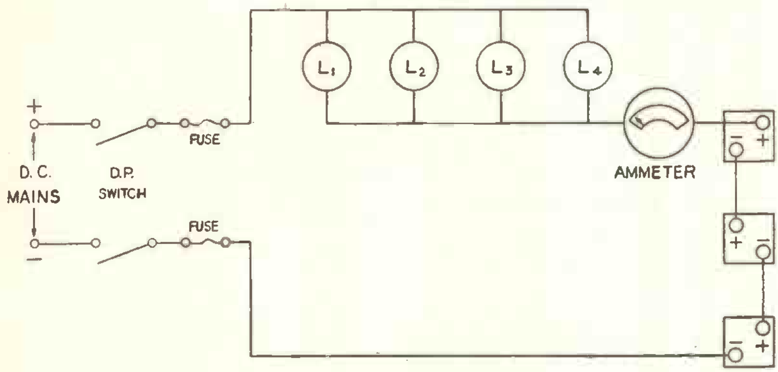


Fig. 2.—The Circuit of a D.C. Mains Charger.

L1–L4 are current regulating lamps. The batteries must never be connected or disconnected while the mains switch is closed, because there is always danger of shock from the batteries when charging from D.C. mains.

The Voltage of Resistance Lamps

The voltage rating of the lamps used for the charging resistances is not important, so long as it is not less than the difference between the voltage of the mains and that of the battery on charge. Since the number of cells on charge is likely to vary a good deal, it is most convenient to use lamps of the same voltage as that of the supply mains. By this means the lamps are always underrun, so that they have an almost indefinite life.

A Useful D.C. Charging Board

Fig. 3 shows a D.C. charging board suitable for charging three batches of

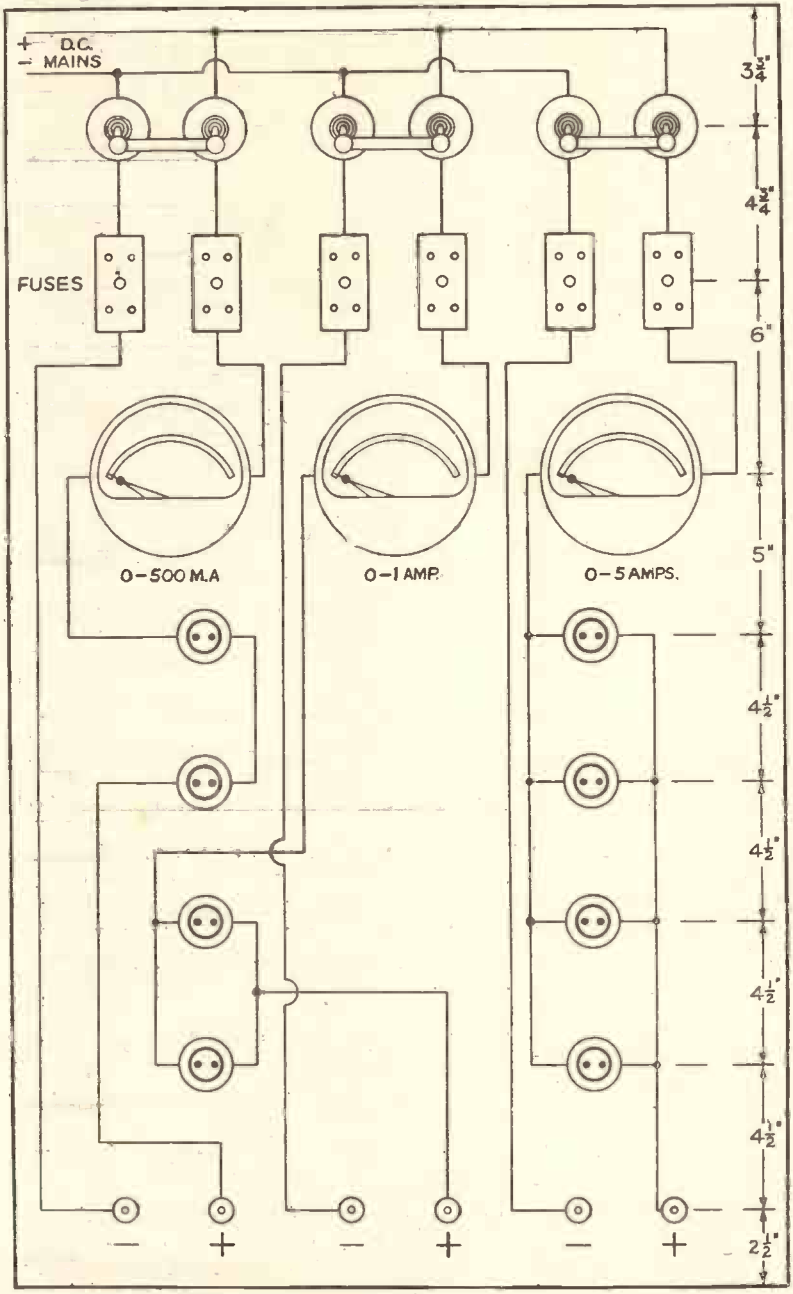


Fig. 3.—A Design for a D.C. Charging Board giving Three Independent Charging Currents.

This is suitable for charging both high- and low-tension batteries simultaneously.

cells at independent rates. The materials required are as follows:—

Deal to make panel 24 × 40 inches.

Batten 2 × 1 inch, 6 feet.

3 5-amperes double pole tumbler switches.

6 5-amperes porcelain fuse boxes.

4 inch moving iron ammeter 0–5 amperes. Projecting pattern.

4 inch moving iron ammeter 0–1 ampere. Projecting pattern.

4 inch moving coil milliammeter 0–500 milliamperes. Projecting pattern.

8 batten type L.B.C. lamp holders.

6 insulated terminals.

25 yards of single 3·029 lead covered cable.

Anti-sulphuric acid paint and twin 3·036 lead covered cable for the mains connection. (Cost with meters, about £10.)

The provision of three separate double pole switches permits one of the charging circuits to be connected up, without fear of shock, whilst the other two are in use. Separate fuses are necessary for each circuit because each has a different maximum current.

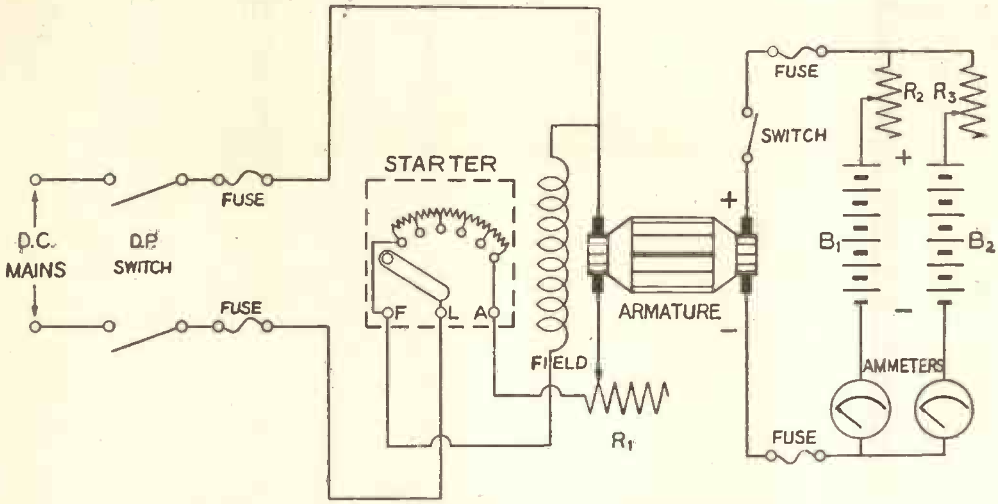


Fig. 4.—THE CIRCUIT OF A D.C. TO D.C. ROTARY CONVERTER.

A rotary converter enables low voltage batteries to be charged from high voltage mains more economically than through lamp resistances. The rheostat R_1 is for controlling the output voltage. R2 and R3 regulate the currents in the separate banks of cells, B1 and B2.

Construction of Switchboard

The wiring of the switchboard is carried out with lead-covered wire so as to minimise the effect of acid fumes from the batteries. All the wiring is concealed below the board. Battens are used to clamp the boards of the panel together and to provide a recess at the back to house the wiring. In wiring up the components do not bare more lead than is necessary, so as to protect the wire to the maximum extent. Before mounting the parts, the panel is given two coats of acid-resisting paint.

Rotary Converters

Low-tension battery charging from D.C. mains through lamp or other regulating resistances is a particularly inefficient method when the mains voltage is high and the number of cells is small. When the total voltage of the batteries charged is usually less than half that of the mains, it is safe to assume that it is worth while to instal a rotary converter.

A D.C. to D.C. rotary converter is a combination of a motor and dynamo in one machine. These machines are designed to run as a motor when connected to the supply mains, and to deliver from a second commutator on the armature a different voltage from that of the supply. Fig. 4 shows the circuit of a 35 volt rotary converter charging plant, for charging up to a maximum of twelve 2-volt cells in series. When it is desired to charge more than twelve cells at once the cells are divided into parallel batches, with a regulating resistance and ammeter in each branch circuit, as shown.

Polarity of Mains

It is essential to connect the positive of the charging supply to the positive pole of the battery, and the negative to the negative. Before connecting to D.C. mains it is necessary to identify the polarity of the mains. This is done in the following way :—

Connect a pair of wires to the charging terminals of the charging board with one lamp in circuit. The bared ends of the wires are then held apart in a glass of slightly salted water. The positive wire will gas less than the negative one. Another method is to use a moving coil voltmeter or other directional type of measuring instrument.

CHARGING FROM A.C. SUPPLIES

Methods

There are three principal systems of charging batteries from A.C. mains. When an A.C. supply is used it is not only necessary to reduce the voltage, but also to rectify the current to D.C. The usual equipment therefore consists of a step-down mains transformer and a rectifier of either the valve or metal oxide type. The relative merits of valve and metal rectifiers is discussed on p. 463. A third method of charging from A.C. is to use an A.C. to D.C. rotary converter. This method is to be preferred only when the charging current is over 3 amperes, so that for the charging of wireless accumulators, where the usual current is ½ to 1 ampere, the A.C. to D.C. synchronous rotary converter is not recommended.

Design for Small A.C. Charger

This charging plant is made up from standard Westinghouse rectifiers and mains transformers. It gives three independent D.C. outputs. The two low tension outputs will charge six cells at ½ to 1 ampere, and up to four 2-volt cells at 1 to 2 amperes. The circuit diagram is shown in Fig. 5. Two transformers are used to secure the greatest efficiency, although one special transformer with three secondary windings would suffice.

The power taken from the mains is only 100 watts at full load on all three outputs, so that no special power leads to the switchboard are necessary. The secondary winding of the high-tension charging transformer is provided with a voltage tapping at 150 volts to give an efficient means of regulating the current when lower voltages of H.T. batteries are to be charged. It is essential to use ammeters of the moving-coil type to indicate the charging current. Although moving iron ammeters are suitable for measuring direct and alternating currents, they give the wrong kind of reading on rectified A.C. which is unsmoothed.

Maximum Charging Current

The maximum charging current which may be drawn from the H.T.8 rectifier is 60 milliamperes. The 3,000 ohm rheostat must have a rating of at least 12 watts, and the working voltage of the 2 mfd. condensers is 200 volts. By means of the double-pole double-throw switch, the input voltage to the H.T. rectifier can be reduced to 150, so that it is possible to charge as few as ten cells without the use of a large and wasteful rheostat. With the 150-volt input, the H.T. circuit is used for charging up to seventy cells in series. When charging more than seventy cells the full voltage is applied to the rectifier.

For Maximum Efficiency

When the number of cells on charge is likely to vary a good deal, the secondary or output windings of the mains transformers should be provided with voltage tappings so that the current may be regulated with the minimum of resistance in circuit. The chief advantage of charging from A.C. supplies is the ease and efficiency with which the voltage can be adjusted to that of the battery on charge, and the nearer the charging voltage is to that of the battery, the greater will be the efficiency. The voltage of the charging current must always exceed the battery voltage by a small amount. It is not necessary to measure the rectified voltage; it is simply necessary to adjust the transformer voltage until the required charging current is obtained. There is no fear of the battery discharging through the rectifier if the D.C. voltage is too low when first switching on.

DYNAMO CHARGING

Charging from a dynamo is resorted to only when there are no supply mains available. Sometimes it may be economical to instal a dynamo when there is an existing workshop shaft driven from an electric motor.

The Prime Mover

When it is necessary to provide a self-contained generating set the question of the most suitable engine arises. Undoubtedly the cleanest and generally the most economical form of power is a petrol or oil engine. A self-contained petrol-electric generating set will be the most suitable for ordinary requirements. The engine is preferably direct-coupled to the dynamo.

Kind of Dynamo Required

For accumulator charging it is essential to use a shunt wound dynamo. Both series

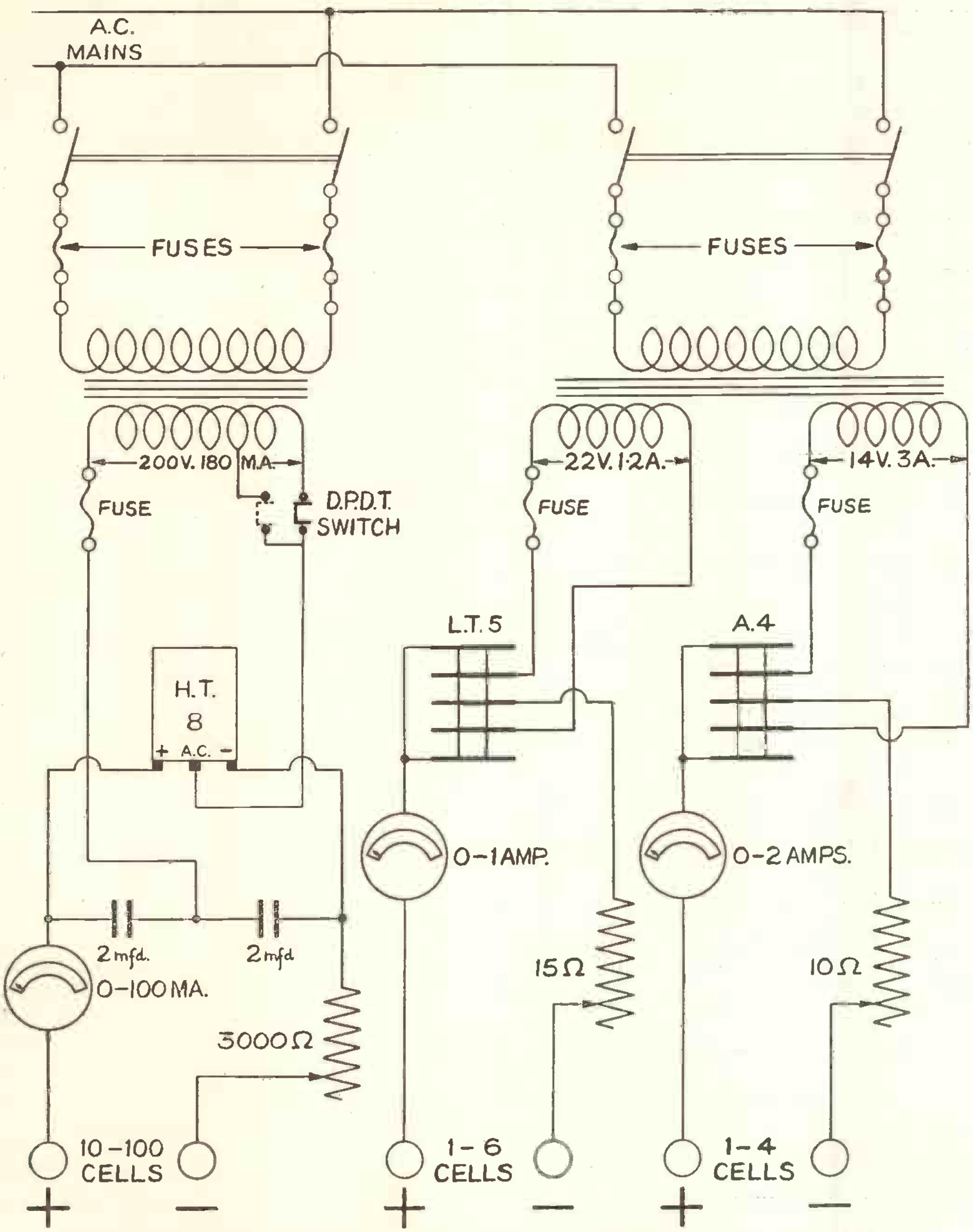


Fig. 5.—An A.C. Charging Equipment giving Three Separate Outputs.
The same circuit can be used with larger rectifiers and transformers to suit different requirements.

and compound wound machines are to be avoided for this purpose, because there is always a possibility of the battery reversing the residual magnetism of a series or compound wound dynamo.

Size of Dynamo

The maximum voltage required from a battery charging dynamo is found by multiplying the number of cells by 2·7. Suppose it is desired to charge twenty cells at once, a 54-volt dynamo is necessary. The current required from the dynamo will be the same as the charging current of the largest cells. For charging wireless cells a maximum current output of 3 amperes will be sufficient. If car batteries are to be handled as well, a dynamo giving a maximum current output of about 10 amperes is advisable. Dynamos are rated to deliver so many watts at a certain voltage. The watts output of a dynamo is found by multiplying the maximum current by the voltage of the machine. Thus, if a machine is required to give 54 volts at 3 amperes, a machine of 162 watts output is required. There is no harm in having a dynamo of somewhat greater capacity than is required because the output is easily regulated by means of a rheostat in the field circuit. It is essential to specify the speed of the dynamo when buying a machine, because a dynamo is always designed to give its rated output at a definite speed.

A Typical Example

The following is an example specification of a charging dynamo :—

Output : 200 watts at 75 volts.
Speed : 2,500 r.p.m.
Pulley : $4\frac{1}{2}$ inches diameter.
Winding : Shunt.
Type : Totally enclosed.

Charging Circuit

Fig. 6 shows the circuit of a dynamo charging plant. A cut-out is used to prevent the batteries from discharging if the engine should fail, or the driving belt slip. This device also automatically connects the dynamo to the battery when the dynamo voltage just exceeds the voltage of the battery. A Nevile or polarised type of cut-out is preferable, because this type of relay is more independent of the dynamo voltage than other types.

The rheostat R is the shunt regulator, by means of which the voltage output of the dynamo can be adjusted to give the required charging current. The value of the resistance will depend on the size and design of the dynamo. A resistance of the same ohmic value as that of the field will usually give sufficient regulation.

HOW TO CHARGE

Rate of Charge

The charging rate, stated in so many amperes, must never be exceeded. This remark applies more especially to the slow discharge type of cell with thick plates, which is popular for wireless use. Batteries may always be charged at a lower rate than the normal without any harm to the cells. It is beneficial to the cells to charge at the normal rate until the plates commence to gas, then finish at half the normal rate. The life of old cells, in which the plates have started to shed, may be prolonged to some extent if they are regarded as smaller cells and charged at a reduced rate.

Duration of Charge

The duration of the charge depends on the condition of the battery and the manner in which it has been discharged, so that it is necessary to have a reliable method of determining when a battery is fully charged. It is very important to be sure that cells are always fully charged before discharging. If cells are frequently put into use before they are properly charged they will sulphate badly.

How to Judge whether a Battery is Fully Charged

There are several methods of judging whether a battery is fully charged. These are as follow :—

1. By the voltage of the cells.
2. By the gassing of the plates.
3. By the specific gravity of the acid.
4. By the duration of the charge.

It is not safe to judge the condition of the charge by any one of these methods used alone. The voltage of a fully charged lead cell lies between 2·5 and 2·7 volts, so that it may be assumed that a battery is not fully charged until it reads at least 2·5 volts per cell, but this reading does not necessarily indicate that the battery is fully charged. The voltage of a fully charged battery depends on the strength of the acid, the rate of charge, the age of the cells and the temperature of the acid. It will be seen, therefore, that a mere voltage test to indicate a fully charged condition can be very misleading.

A Fairly Reliable Method

A fairly reliable method of regulating the length of charge by voltage test only is to charge until the voltage of each cell remains constant for a period of one hour. The voltage readings are taken while the battery is actually on charge.

Gassing of the plates is only a rough guide to the extent of the charge, because the plates commence to gas long before the charge is complete. It is certainly safe to assume that a cell is not fully charged until the plates are gassing freely all over.

The Practical Method

The practical method of judging a fully charged condition is to measure the specific gravity of the acid after the plates have been gassing freely for about one hour. If the acid has by that time reached the fully charged density specified on the cell it is usually safe to judge the cell to be fully charged. Specific gravity readings must be taken with some precautions because the strength of the acid depends on other factors besides the state of the charge. Do not take specific gravity readings directly after topping up with distilled water. Always top up before charging to ensure that the water is well mixed during the charge. Hydrometer readings should be taken after the charged cells have been disconnected for at least an hour.

If specific gravity readings are taken whilst the battery is on charge, the readings are lower than the condition of the charge should indicate. The acid is not of uniform strength during charge, but stronger near the plates and weaker in the bulk of the electrolyte from which the acid is drawn for tests.

Using the Hydrometer

Before use, a new hydrometer is rinsed out with distilled water, then with acid of battery strength. When taking readings, hold the hydrometer vertical so that the float does not bear on the side of the tube. The hydrometer should be agitated to ensure that the float is not adhering to the side of the tube. When the acid is returned to the cells care should be taken not to spill any fluid on the tops of the cells. After a hydrometer has been used it is naturally wet with acid on the outside, and must not be laid on a wooden bench or metal surface. A tall glass jar forms a suitable receptacle for the hydrometer when it is out of use.

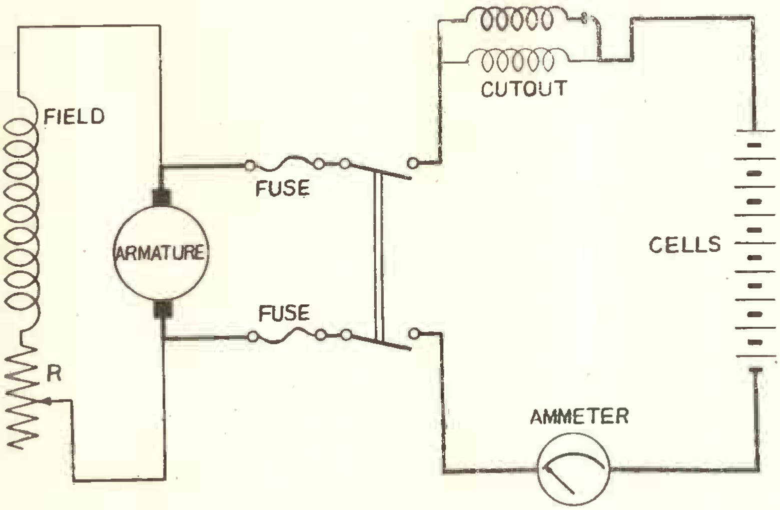


Fig. 6.—THE CIRCUIT OF A DYNAMO CHARGING PLANT.

The automatic cut-out prevents the battery from discharging when the engine speed falls, also automatically connects the cells to the dynamo when its voltage exceeds that of the battery.

Adjusting Acid

It will be frequently necessary to adjust the acid density of some of the cells brought to the charging station. Adjustment is necessary only because spilt acid has been replaced with water, or with acid of the wrong strength. Whenever acid is spilt from a battery it must always be replaced by acid of the same strength.

The normal evaporation is made up with distilled water, nothing else. Sometimes it may be found that the acid in a particular cell will not reach its full specific gravity, even after an extended charge. At the same time the electrolyte evaporates more than usual during the charge. This is because the acid is too weak.

Weak acid is brought up to strength by adding not pure acid, but diluted acid. The diluted acid used for increasing the strength of the battery acid is made stronger than the normal for the cells. Acid of 1,300 specific gravity is useful for this purpose. After adjusting the specific gravity of the acid a cell must always be put on charge so as thoroughly to mix the electrolyte. When it is necessary to reduce the strength of the acid, some of the fluid is withdrawn from the cell and replaced with distilled water.

The adjustment of the electrolyte in a cell is not an easy matter, because it is not possible to measure the resultant specific gravity after adjustment until the cell has been charged and allowed to stand.

How to Mix Acid

Sulphuric acid is a corrosive substance and must not be allowed to come into contact with any fabric, concrete, wood or metal articles other than lead. Strong acid rapidly chars organic substances and burns the hands. If acid is accidentally spilt or splashed on the clothes and hands it is immediately rendered harmless by the application of liquid ammonia, washing soda, bicarbonate of soda or powdered chalk, whichever is first to hand. A strong solution of washing soda should be kept handy for this purpose.

Diluted acid is always made up by adding the strong acid to the distilled water, not *vice versâ*. The acid is added a few drops at a time. Stir the solution after each addition of acid and do not allow the liquid to become hot. It is not advisable to mix one's acid as a general rule, but rather to stock several strengths of diluted acid as previously mentioned.

Situation of Apparatus

The charging apparatus should be situated some distance from the cells themselves so as to avoid corrosion of the switches and other parts on the charging board. It is more particularly important to protect the metal rectifiers of A.C. charging gear from the effect of acid fumes, because these components are constructed of metals which are quickly corroded by sulphuric acid. The best plan is to have the switchboard in a room separate from the batteries.

The gas which is given off at the end of the charge is an explosive mixture, so that naked lights must not be allowed in the battery room. Never use a match to examine the level of the electrolyte in a cell with an opaque case.

Nickel-steel Cells

The nickel-steel type of cell requires somewhat different treatment from the lead type of battery. It is necessary to ensure that the charging current does not fall below the normal rate, which is the opposite requirement of lead cells. For this reason it is not advisable to charge lead cells in series with nickel-iron types.

Normal Voltage

The normal voltage of a nickel-iron cell is $1\frac{1}{4}$ volts, and the strength of the electrolyte does not vary during charge and discharge. It is therefore not possible to gauge the duration of charging by the specific gravity of the electrolyte, which is chiefly caustic potash and not acid like that of the lead battery.

Evaporation of Electrolyte

The evaporation of the electrolyte is made up with distilled water in the usual way. These cells gas the whole time they are on charge, so that gassing is no indication of the condition of the charge. Nickel-iron cells are charged until the voltage per cell has remained constant at 1·7–1·8 volts for at least one hour. There is no fear of injury to this type of cell through overcharging, or charging at many times the normal rate.

The electrolyte of this type of cell is usually a mixture which should be obtained from the manufacturers of the cell. In case of emergency it is fairly safe to replace spilt electrolyte with a 20 per cent. solution of pure caustic potash.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XV—DETECTION OF WIRELESS SIGNALS

THERE is a good deal of confusion in the mind of an average listener in connection with detection of wireless signals. Many think that all a detector does is to rectify oscillating (alternating) currents, *i.e.*, convert them into a series of unidirectional pulses, and that is all there is to it.

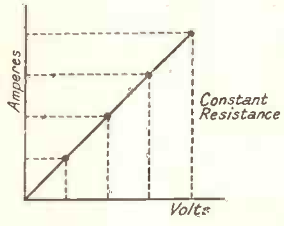


Fig. 1.—VOLTAGE-CURRENT CHARACTERISTIC.

In order to be able to appreciate the actual happenings in the detector circuit we shall have to study first of all the behaviour of unidirectional conductors and then see how this property is used in the detection of wireless signals.

Voltage-current Characteristic

In the case of an ordinary metallic conductor, such as a length of wire, provided that the temperature of the conductor remains constant, the resistance of the conductor is always the same and the current will depend upon the voltage. The voltage-current characteristic in this case is merely a straight line, such as shown in Fig. 1.

You can see from this graph at a glance that as the voltage increases the strength of the current increases.

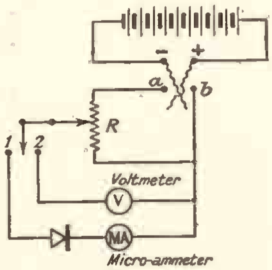


Fig 2.—TYPICAL CRYSTAL CIRCUIT FOR TAKING CHARACTERISTIC CURVES OF ANY COMBINATION OF CRYSTALS.

Now, it does not matter how we connect this conductor in the circuit, the characteristic will always remain the same. This means that the conductivity of the conductor is exactly the same in both directions.

Conductivity of Crystals

If, instead of an ordinary conductor, we connect in our circuit a crystal and a "cat's whisker" or a combination of two crystals, we shall find that the conductivity of the crystal in the two directions differs considerably. Such a crystal combination may have a large conductivity in one direction and none or very little in the opposite direction. Why this should be so is not yet definitely determined, and many theories have been put forward at various times.

Measuring the Current through a Crystal

The circuit shown in Fig. 2 will enable you to take the characteristic curves of any combination of crystals you like. The two flexible leads from the battery will enable you to change the direction of current through the crystal, and the potentiometer R will allow you to vary the voltage applied across the crystal at will. In this manner you can measure the current through the crystal in both directions at any voltage. The resultant characteristic will be of the nature of the graph shown in Fig. 3.

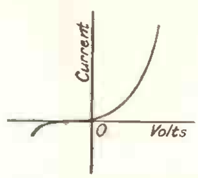


Fig. 3.—GRAPH SHOWING CURRENT THROUGH A CRYSTAL IN BOTH DIRECTIONS AT ANY VOLTAGE.

This graph shows at a glance that the crystal will allow a large number of electrons to pass, say, from right to left, and hardly any can go through from left to right (Fig. 2).

How an Alternating Current can be converted into Direct Current

Fig. 4.—A Crystal connected across a source of Alternating Current.

Therefore, if we have an arrangement such as shown in Fig. 4, and if we assume that the crystal will pass the current only from left to right and none at all from right to left, we shall find that every half-cycle of our alternating current is wiped out by the crystal and the alternating current becomes a series of unidirectional pulses, as shown in Fig. 5. The reason for this is that as the upper brush of our alternator becomes more and more negative, electrons will pass through the crystal in increasing numbers and will follow the variations of the intensity of the E.M.F. But when the lower brush of the alternator becomes rich in electrons during the next half-cycle the crystal will stop the flow of electrons in the opposite direction and there is no current flowing at all or so little as to be negligible in practice. You can see from Fig. 5 that the series of rapid unidirectional pulses is equivalent in practice to an average direct current; current flowing in the circuit the magnitude of which will be a mean average value lying between the zero and the maximum amplitude of the pulses. This is how an alternating current can be converted into a direct current.

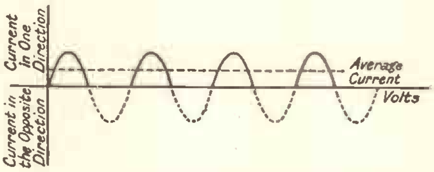


Fig. 5.—Showing how every Half Cycle of the Alternating Current is Wiped out by the Crystal and the Alternating Current becomes a series of Unidirectional Pulses.

Thermionic Valve is also a Unidirectional Conductor

A thermionic valve is also a unidirectional conductor. In Fig. 6 we have an alternator connected across a two-electrode valve. As we already know, inside the valve electrons will flow *from the hot filament* to the anode, especially if the latter is made positive. Now, if the upper brush of the alternator happens to be negative, it will make the anode of the valve negative too, and the latter will repel the electrons reaching it from the filament so that no electrons will be able to land on the anode and therefore there will be no current flowing through the valve.

Fig. 6.—An Alternator connected across a Two-electrode Valve.

But when the upper brush of the alternator is positive, the anode will become positive and a current will flow from the filament to the anode. The alternating current will once more become a unidirectional current, as shown in Fig. 7. As you see, in this case the current is flowing in the opposite direction to that described above.

Half-wave Rectification

Such rectification is called *half-wave rectification*, as only half of the current "wave" (the shape of the curve in Figs. 5 and 7 resembles a wave, and so we talk about a current *wave*) is wiped out during each cycle. It is possible to have a full-wave rectification, so that each half-wave is wiped out alternately during each cycle. The arrangement capable of performing this feat is shown in Fig. 8. In this case the source of alternating E.M.F. is connected across the primary of a transformer. The secondary of the transformer is connected across the anodes of the two valves. A centre tapping is taken from the secondary of the transformer. Now let us suppose that the point A (Fig. 8) is negative during the first half-cycle. This will make the anode of the upper valve also negative, so that no current will flow through the upper valve during that half-cycle.

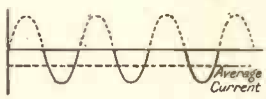


Fig. 7.—Showing how the Alternating Current once more becomes a Unidirectional Current.

Since the point A is negative, the point B must be positive, as the surplus of electrons at A has been obtained at the expense of B, and since the point B is positive, the anode of the lower valve is also positive, and a current will flow through the lower valve.

When the point A becomes positive during the next half-cycle and the point B, of necessity, becomes negative, it is the upper valve that will let the current through, and the lower valve will remain inactive. Thus, during each half-cycle, each anode in turn will become positive and will rectify the alternating current flowing through the secondary of the transformer.

In practice only one glass bulb is used and the two anodes are housed in it, as shown in Fig. 10. The action of this arrangement is precisely the same.

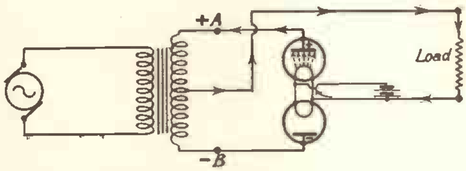


Fig. 9.—This shows the Current flowing through the Second Valve.

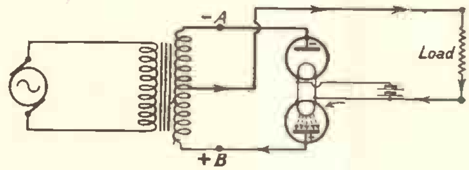


Fig. 8.—Arrangement for Full-wave Rectification.

Alternating Current in an Aerial System

An aerial system such as shown in Fig. 11 can be considered as a source of alternating E.M.F. if it is receiving a regular alternating wireless wave. If the crystal will pass a current when the point A is negative we shall have a pulsating current flowing each half-cycle, as shown in Fig. 12. In the case of Fig. 13, when the point A is negative the grid of the valve will be negative too, and, provided that the negative charge on the grid is sufficiently large, no current will flow from the filament to the anode. When the point A is positive, the grid will become positive and will assist the anode so that a current will flow through the valve.

Direct Component of Anode Current

Now, in the case of the valve, if we disconnect the valve from the aerial system and leave all the remaining connections as they are, *i.e.*, leave the filament and the H.T. batteries connected to the valve, we shall have the grid at zero potential. This being the case, a steady current of constant strength will flow from the filament to the anode. This current being a unidirectional current, *i.e.*, a direct current, is called the *direct component of anode current.*

Suppose that we have made the grid positive, instead of its being at zero potential. The current through the valve will increase as the positive grid is helping the anode and is pulling in more electrons from the filament. When the grid is made negative the current will decrease. If the negative charge on the grid is sufficiently large the current will stop. This means that while we vary the potential of the grid the value of the direct component of anode current will be varied, a negative grid reducing the strength of the anode current and a positive grid increasing it.

What Happens when an Alternating Potential is applied to the Grid

When an alternating potential is applied to the grid the value of the anode current will vary with the variations of the alternating potential. From Fig. 15 you can see that this looks as if there is a combination of an alternating current and a direct current. The engineers refer to this added varying current as the alternating component. But it is not an alterna-

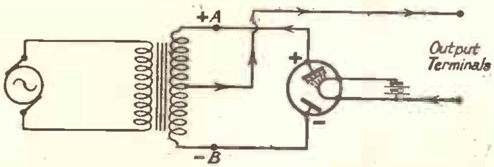


Fig. 10.—In practice only one Glass Bulb is used, and the two Anodes are Housed in it, as shown.

ting component, although its effect, say on a transformer, is the same as that of a similar alternating current.

The varying component is still a unidirectional current varying in value above and below of the steady component of the anode current, but is never zero, and never reverses its direction. If it did that it would have to be shown during each half-cycle below the zero line.

It is clear that the variations of grid potential first reduce and then increase the strength of the current flowing through the valve, but there is no alternating current flowing through the valve, as this would mean that the current would have to flow now from the filament to the anode and now from anode to the filament.

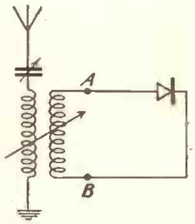


Fig. 11.—The Aerial System shown can be considered as a source of Alternating E.M.F. if it is receiving a regular Alternating Wireless Wave.

Modulated Waves

If you remember from my previous articles, in broadcasting we combine high-frequency currents (carrier current) with much slower microphonic currents so that, as a result, we have a modulated carrier current and therefore a modulated carrier wave. This modulated wave will induce in our aerial system a modulated current such as shown in Fig. 16. This, as you can see, consists of a combination of two kinds of currents, the high-frequency current, which is merely a convenience, and the microphonic current varying much more slowly. There is a series of variations in the modulated portion of the current curve, a large number of current "waves" or a train of waves which may represent a certain sound or a combination of sounds.

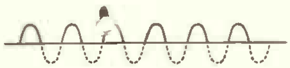


Fig. 12.—When the Point A in Fig. 11 is negative, a Pulsating Current flows during each Half-cycle.

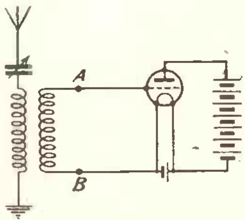


Fig. 13.—The Aerial System connected to a Valve.

Fig. 14.—When the Point A in Fig. 13 is Positive, the Grid will become Positive and a Current will flow through the Valve.

Since any rectifying device, such as a crystal or a valve, cuts off every half-cycle, the first thing that a crystal or a valve will do to the varying induced E.M.F. causing the current is to convert it into a series of unidirectional pulsations, as shown in Fig. 17.

What the Detector actually has to do

Thus we have a series of unidirectional pulses occurring at high frequency and combined with the microphonic currents. Our job now is to get rid of the high-frequency impulses and to impress upon the reproducing system the slower microphonic variations in such a way that in our telephone or loud speaker windings only currents having microphonic characteristics are flowing. This is what the detector does in the circuit.

THE CRYSTAL AS A DETECTOR

Let us start with the crystal.

In Fig. 18 we have a typical crystal receiving circuit. When the electric alternating field establishes itself between the aerial and earth an alternating E.M.F. comes into existence between the points A and B. When the tuning system of the crystal receiver is tuned precisely to the desired incoming wave the corresponding E.M.F. will be at every instant at its greatest possible intensity as compared with E.M.F.'s induced by any other wave.

Current Flowing during First Half-cycle

Let us assume, for argument's sake, that the crystal will conduct electrons from left to right. Thus, when the point A becomes rich in electrons a current will flow through the crystal and round the circuit. Since the potential at A is an alternating one, the current flowing through the crystal during the half-cycle will be a current starting from zero, growing gradually but very quickly to a maximum and then diminishing to zero again. The electrons starting to flow from the point A, which is made rich in electrons by the aerial, while the point B is made poor in electrons (with a predominance of protons), will flow from the point A to the point C.

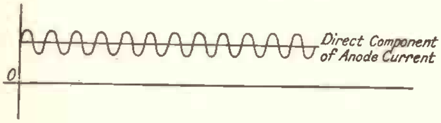


Fig. 15.—Diagram illustrating Direct Component of Anode Current.

At this point they will find that the self-inductance of the telephone windings is offering too much opposition for them to flow through the telephones, and for this reason they will proceed along the line of least " resistance " and will settle on the upper plate of the condenser, which is connected across the telephones.

Accumulation of Electrons on the Condenser

This will cause an equal number of electrons to retreat from the lower plate of the condenser and drift towards the point B. The condenser across the telephones will thus acquire a charge. The charge will gradually increase as the current grows during the half-cycle. This charge is not large enough to enable the condenser to discharge through the telephone windings when the applied E.M.F. becomes zero, and so it remains on the condenser for the time being.

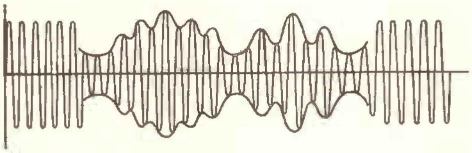


Fig. 16.—Modulated Current induced in an Aerial System by a Modulated Wave.

Current Flowing during Second Half-cycle

Now, when the point A becomes positive during the next half-cycle the crystal will not allow the electrons accumulated on the upper plate of the condenser to drift towards A, as no current can flow through the crystal from right to left. Hence the charge on the condenser will remain intact throughout the next half-cycle. When the point A becomes negative once more a few more electrons will be added to the upper plate of the condenser across the telephones and the charge will gradually grow during each half-cycle till it is large enough to discharge itself through the telephones.

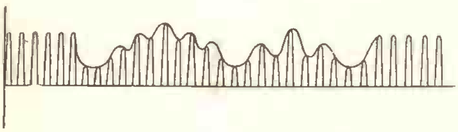


Fig. 17.—Showing how a Rectifying Device converts the varying induced E.M.F. causing the Current into a series of Unidirectional Pulsations.

Each High-frequency Impulse gives an Additional Charge to the Condenser

If you look once more at Fig. 17 you will realise that it is each high-frequency impulse that gives an additional charge to the condenser. Since the charge must have time to accumulate, the discharge current will be much slower and will not follow the high frequency of the carrier current but the slow variations of the microphonic current. In other words, the discharge current of the condenser will be an exact copy of the microphonic currents, and hence the telephone diaphragm will vibrate in precisely the same way as the microphone diaphragm was vibrating. The current through the telephone will be therefore of the form shown in Fig. 19.

It is not essential to have a condenser across the telephones, as the telephone windings possess sufficient self-capacity to act as a sort of a condenser, and the action will be the same, the charge accumulating across the telephone windings.

THE VALVE AS A DETECTOR

Now let us see what happens when our detector is not a crystal but a valve.

Anode Bend Rectification

Fig. 20 shows a circuit adapted for the purpose of the so-called *anode bend rectification*. The reason for the use of the word *bend* is that the grid bias of the valve is normally chosen so that the working value of the direct

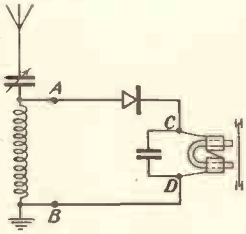


Fig. 18. — A Typical Crystal Receiving Circuit.

component of the anode current, *i.e.*, the normal current, lies on the bend of the characteristic curve. At such a value of anode current, when the working point lies on the lower bend of the curve (there is also an upper bend which can also be used), there is, for a given change of grid voltage, a larger increase than decrease of anode current.

Effect of Increasing or Decreasing Grid Voltage

Let me make this point clear. Suppose at a negative voltage on the grid of −3 volts there is a current flowing through the valve of 0·25 milliamp. If the grid volts are reduced to −2 the anode current will be, say, 0·625 milliamp. With a grid voltage of −4 it will become 0·0625 milliamp. Now, please note, by changing the grid bias from −3 to −2 volts we have increased our anode current from 0·25 to 0·625, an increase of 0·375 milliamp. By changing the grid bias from −3 to −4 volts we have changed the anode current from 0·25 to 0·0625, a decrease of 0·1875 milliamp.

For the same difference of voltage of 1 volt we have twice as great an increase as compared with the decrease. Thus, provided that we work on the lower bend of the characteristic of the valve, *i.e*, choose our values of anode vcltage and grid voltage so that the anode current has a certain definite value, we shall always have a greater increase in anode current than a decrease for the same change in grid volts.

What Happens when an Alternating Potential is applied

This means that when an alternating potential is applied between the points A and B (Fig. 20) and the potential of the grid

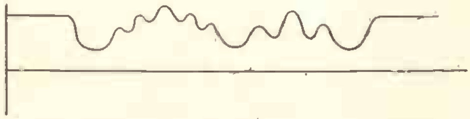


Fig. 19.—This shows the form of the Current through the Telephone.

begins changing, and as there is always a greater increase in current than a decrease, the condenser across the telephones will be charging up and keeping its charge precisely as it did in the case of a crystal receiver. The charge from the condenser cannot escape from the left-hand condenser plate, as electrons cannot pass from the anode of the valve to the filament.

It should be realised that there will be a steady current flowing through the telephones, due to the normal working of the valve, even when the latter is disconnected from the aerial.

In addition to this normal current there will be high-frequency variations in the value of current or a high-frequency component of the anode current which will find it difficult to pass through the telephone windings owing to their self-inductance. The high frequency currents which it must be noted are unidirectional impulses, as the valve only passes current in one direction, will be of the form shown in Fig. 17, and the condenser discharge current passing through the telephones in addition to the normal current of the form shown in Fig. 19.

Importance of Working at the Bend of the Curve

Should the valve be worked not on a bend of the characteristic curve, the discrepancy between increases and decreases in current would not be so pronounced and the condenser across the telephones, or, in the absence of the condenser, the self-capacitative windings of the telephones would fail to acquire a sufficient cumulative charge in order to discharge through the telephones and thus produce audible signals.

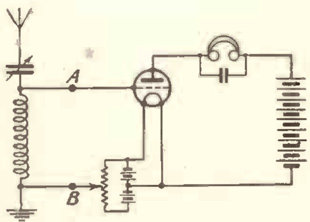


Fig. 20.—A Circuit adapted for the purpose of the so-called Anode Bend Rectification.

Grid-leak Rectification

There is another method

of connecting a valve for rectifying purposes, called *grid-leak rectification*. This is shown in Fig. 21.

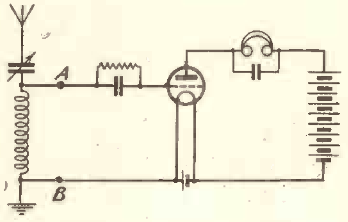


Fig. 21.—CIRCUIT FOR GRID LEAK RECTIFICATION.

While in the anode bend method the grid of the valve is connected directly to the aerial tuning circuit, in the latter method there is a condenser between the aerial and the grid, a condenser with a grid leak (a high resistance) across it. In this case we once more get a larger increase than a decrease in the negative potential of the grid of the valve. Thus, there is once more an accumulation of charges. The way it happens is this.

What the Grid Leak does

When an alternating E.M.F. appears between the points A and B during each positive half-cycle the condenser in the grid circuit becomes fully charged owing to the positive grid attracting electrons on its own from the filament and giving rise to a grid current. The electrons are thus accumulating on the grid and charging up the condenser throughout the half-cycle. The grid leak's resistance across the condenser is so chosen that it represents a timing device and allows the electrons to leak away from the grid or, in other words, it allows the condenser to discharge itself slowly but never completely. The condenser thus accumulates a charge during the positive half-cycle, and slowly discharges itself during the negative half-cycle.

Always a Varying Negative Potential

Since it never discharges completely, the grid always has a varying negative potential which varies the current through the valve. The anode current, for this reason, behaves in the same manner as it behaved in the case of anode bend rectification, and the results are somewhat the same.

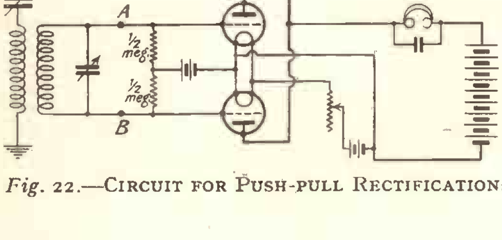


Fig. 22.—CIRCUIT FOR PUSH-PULL RECTIFICATION.

Three Components that Make Up the Anode Current

In the case of the valve used as a detector of signals, we can think of the anode current as consisting of three components; the first component is the steady current through the valve flowing at given anode and grid voltages, when the valve is disconnected from the aerial. This is the *d.c. component* of the anode current. The latter when flowing through the telephone windings, as it does, being of a steady value, produces a constant magnetic field around the telephone windings and for this reason the diaphragm is merely pulled in a little, but does not vibrate.

The second component is the wrongly called alternating component, and which we will call the *high-frequency pulsating component*. This component is added to the d.c. component by the high-frequency carrier current varying in amplitude (modulated) which, owing to its high frequency, is unable to pass through the telephone windings on account of their self-induction that resists all sudden and rapid changes. All this component can do, therefore, is to charge up either directly or indirectly the telephone windings and cause the latter to discharge through themselves.

This discharge current is a current varying at audible frequencies and is, for this reason, called *the low-frequency component* of the anode current.

It is highly essential for every practical man to provide himself with a few measuring instruments and to try out all these three methods of signal detection, comparing carefully the results obtained. A diode as well as a triode should be tried. In investigating the detecting properties of valves it is highly interesting to try out every type of valve one can lay one's hands on as a detector. You are sure to obtain some highly interesting results, especially in the case of the pentode valve.

Push-pull Method of Rectification

In conclusion, it is necessary to mention the push-pull method of rectification. The circuit is shown in Fig. 22. The two valves are carefully matched. The arrangement shown causes one valve to have a grid current, while the other valve has a very small grid current or none at all. Each half-cycle this state of affairs is reversed.

Thus, while the anode current of one valve increases, the current through the other valve decreases. The low-frequency component of both valves changes in step and the current flowing through the telephone windings is the sum of the two.

The advantage of such an arrangement is that it eliminates the use of a grid condenser which prevents the use of a high value of grid leak, and the latter is necessary if high notes are to be retained at their proper value. The push-pull arrangement seems to be a compromise between the anode bend and the grid leak method of rectification. It is claimed that good results can be obtained by this method.

CURRENT CONSUMPTION OF LAMPS

This table is intended for use when charging accumulators from D.C. supply, using lamp resistances, an example of which is given on p. 970.

Watts Rating.	Current, Amperes.							
	100 volts.	110 volts.	200 volts.	210 volts.	220 volts.	230 volts.	240 volts.	250 volts.
15	·15	·136	·075	·0715	·068	·065	·0625	·06
25	·25	·227	·125	·119	·114	·108	·104	·1
40	·4	·36	·2	·19	·18	·174	·167	·16
60	·6	·55	·3	·286	·27	·26	·25	·24
75	·75	·68	·375	·357	·34	·326	·312	·3
100	1·0	·91	·5	·475	·455	·435	·415	·4
200	2·0	1·8	1·0	·95	·91	·87	·835	·8
300	3·0	2·7	1·5	1·44	1·36	1·3	1·25	1·2
500	5·0	4·5	2·5	2·38	2·27	2·17	2·08	2·0

H.M.V. AUTOMATIC RECORD CHANGERS

USED ON MODELS 117 PLAYING TABLE, 522 RADIO GRAMOPHONE, 531 RADIO GRAMOPHONE

The Correct Way to Load the Records

ONLY records of one size (either 10-inch or 12-inch) can be played at one setting.

Place the selected records on the supporting plates, bearing in mind that the bottom record in the pile will be the first to be played, and so on. Make sure that the spindle WS (Fig. 4) is in position and pushed home.

Now turn the indicator knob NR until the desired number of selections is indicated on the dial.

If only three records are chosen, and it is desired to play the last selection (Top record) three times, the knob NR should be set to No. 5.

A single record may be loaded and reproduced any number of times up to eight by setting the indicator at the required figure.

How to Start the Mechanism

Press the starting button SB (Fig. 4) right in, close the lid of the cabinet and turn the volume control in a clockwise direction from the minimum position until the desired volume is obtained.

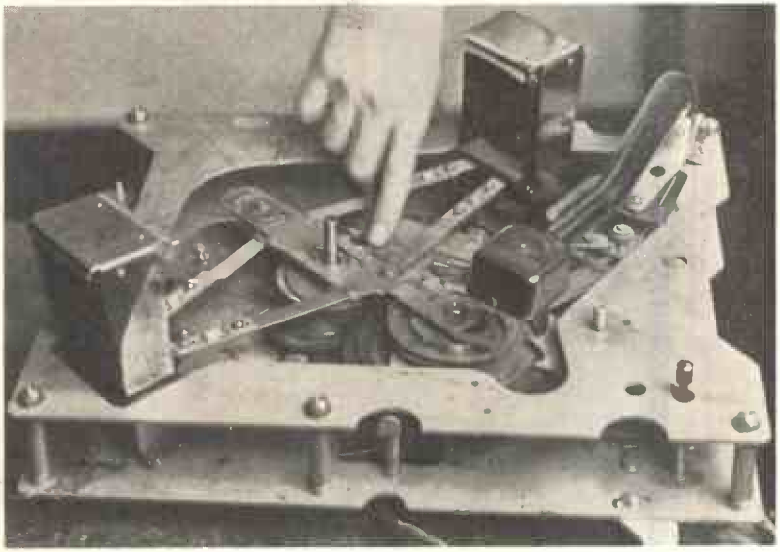


Fig. 1.—DISENGAGING THE CLUTCH TRIP LEVER.

How to Stop a Record in the Middle

Press the starting button SB, when the record will be automatically rejected and the next record introduced.

After the last "playing" the mechanism will automatically return the indicator knob NR to the "OFF" position and the motor will be switched off.

Before removing the played records from the turntable the spindle WS must first be removed.

What to do if a Record Sticks

Do NOT USE FORCE. Proceed as follows :—

(1) Switch off the instrument.

(2) In the case of 12-inch type records rotate the turntable in an anti-clockwise

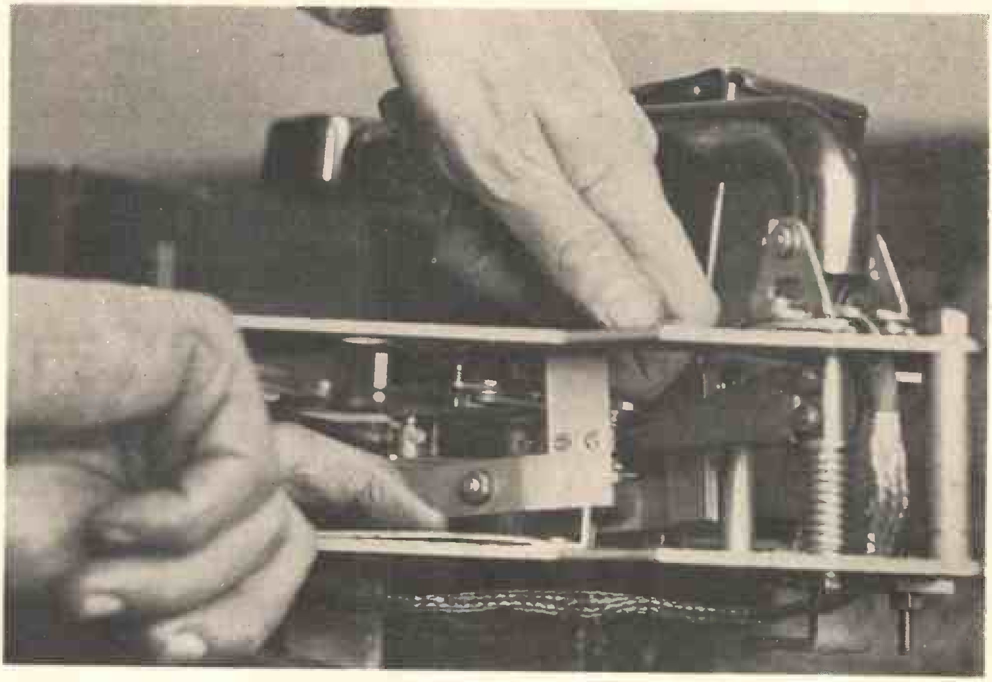


Fig. 2.—The Pick-up Lifting Lever and Cam.

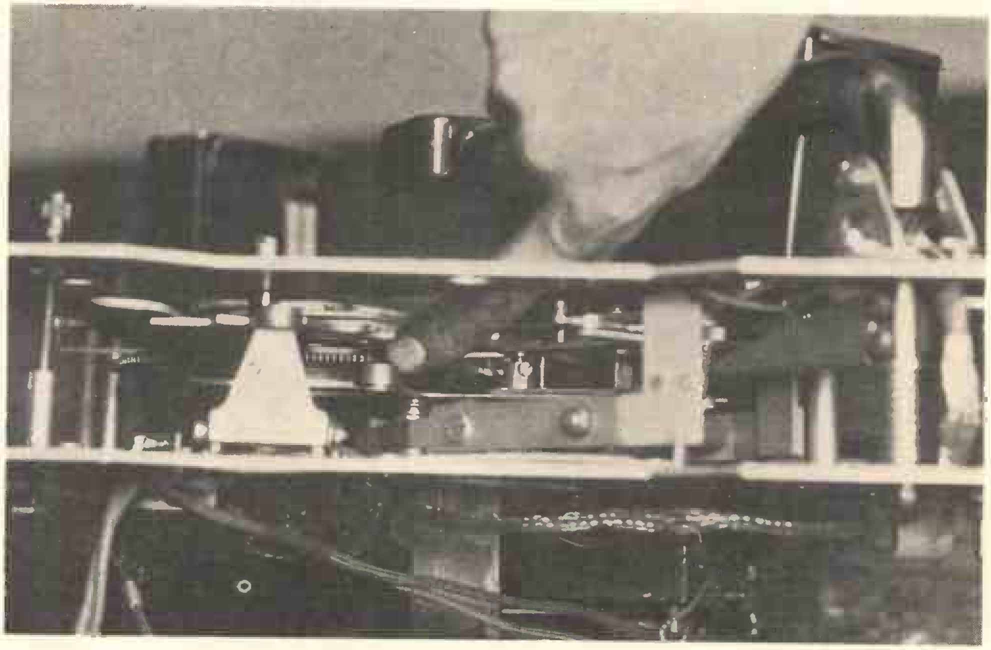


Fig. 3.—The Lifting Cam Roller.

direction to relieve any strain on record or spindle (WS). In the case of 10-inch, gently move the knob JA (Fig. 4) towards back of cabinet to open the record fans.

(3) Remove spindle and any records above the record which has stuck.

(4) Remove the record in question, if necessary gently lifting the top record plates to do so.

A record which has stuck in the plates should be noted and examined to see whether it is warped or damaged.

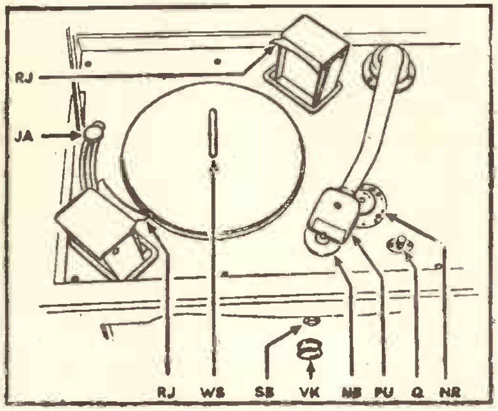


Fig. 4.—THE CONTROLS OF THE AUTO-MECHANISM.

RJ, record jaws; JA, knob adjusting jaws for 10" or 12" records; WS, withdrawable spindle; SB, clutch tripping or record changing button; NR, switch ratchet wheel knob; Q, speed regulator.

Never leave records loaded on the instrument when not in use.

How to get at the Mechanism

It is most important that this operation is correctly performed, otherwise not only may difficulty be experienced in lifting the cover plates, but the mechanism may be strained. Care should also be taken to see that the pick-up arm is not scratched. There is no necessity to remove the pick-up head when removing the metal cover plate.

Remove the six screws securing the metal cover plate to the cabinet and place them in the needle bowl, which should be taken out and put somewhere safe. Next take off the indicator knob of the switch wheel by taking out the small centre screw. When the knob has been removed the pointer can be levered off.

When unscrewing the speed-regulator knob (Q, Fig. 4), count the number of turns necessary to extract it, to facilitate its re-insertion at the correct setting.

The brown moulded cowling round the base of the pick-up arm must now be removed before the cover plates can be lifted off. Remove the three screws securing the cowling, which is in two sections, and slide one section out of the other. Then remove the cowling securing ring, shown in Fig. 5.

Setting the Record Jaws

The knob JA (Fig. 4), which must also be removed, should be moved to and fro so that the supports of the record jaws are *absolutely vertical*, and before attempting to lift off the cover plates the turntable spindle should be turned in a clockwise direction (having pressed the button) until the lower and upper jaw plates are as nearly in alignment as possible so that they occupy the minimum amount of room.

Lifting the Metal Cover Plate off

Unless this is done carefully the pick-up arm may be scratched and the record jaw levers thrown out of adjustment. Having removed the turntable, grasp the needle-box clip and insert one finger under the edge of the turntable spindle hole.

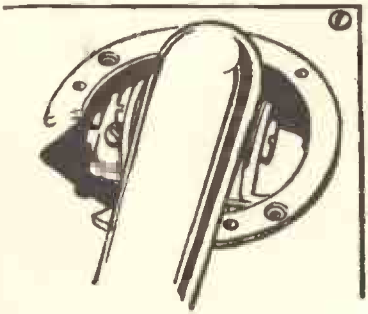


Fig. 5.—THE PICK-UP BASE COWL SECURING RING.

The tone arm should be lifted vertically when this is done. Two persons can do this far more easily than one.

Important

Do not remove the mechanism unless it is absolutely necessary. All important adjustments can be made with the mechanism in the cabinet.

Do not, under any circumstances, try to remove the top frame, which will, if fitted, be found under the metal cover plate.

If it is absolutely necessary to remove the mechanism, lift it out by the cut-outs on either side of the frame, *not by the record jaws.*

Fig. 6.—ADJUSTING THE "LEAD-IN SPRING."

Don't put too much Oil on the Mechanism

It is unlikely that the mechanism will want oiling, but if it is found to be dry use only His Master's Voice oil. This has been specially prepared for the job. Other oils may "gum up" or even corrode the mechanism. Too much oil may cause suction between the various moving surfaces.

How to Replace the Pick-up Arm Base Cowling

Having replaced the metal ring (Fig. 5), place the small back portion of the cowling in position first, then, having swung the tone arm as far as it will go towards the centre of the turntable, slide on the front half of the cowling.

Fig. 7.—ADJUSTING THE DROPPING POSITION OF THE NEEDLE.

WHAT THE MECHANISM CONSISTS OF

The His Master's Voice automatic mechanism is really divided into four sections.

The Motor

A special long-spindle type induction disc motor which is described later.

The Record Jaw Operating Mechanism

This motion opens and closes the jaws (see Fig. 8).

The Clutch Mechanism

This engages with the motor when the record-changing mechanism is set into operation either by the button SB or the movement of the pick-up arms.

The "Trip" Mechanism

This sets the record-changing mechanism in operation by tripping the clutch (Fig. 9).

Figs. 8, 9 and 10 make the ex-

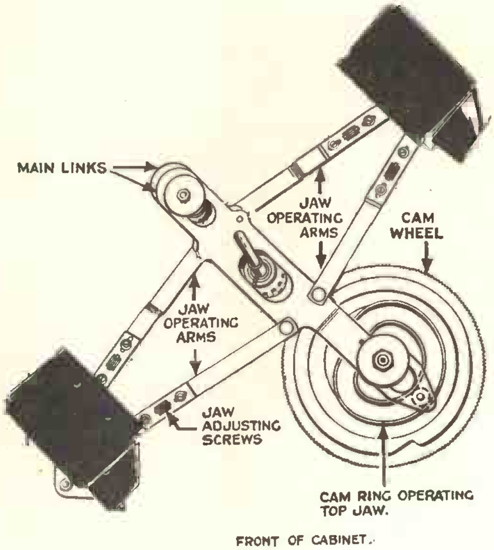


Fig. 8.—Here are shown details of the Jaw Operating Mechanism.
The complete mechanism is shown in Fig. 11.

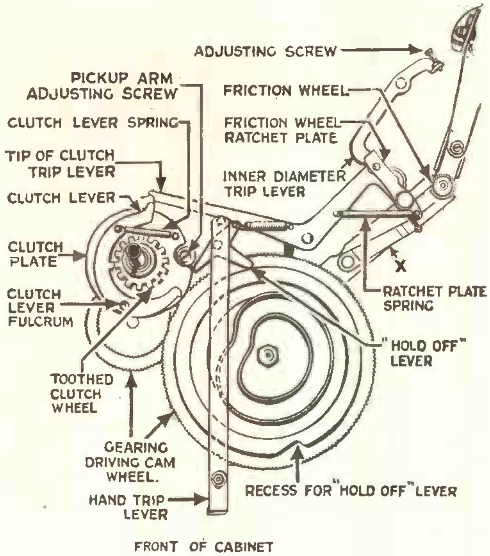


Fig. 9.—This shows the Clutch Tripping Mechanism Star Wheels.
The complete mechanism is shown in Fig. 11.

planation of the erection of the various sections of the instrument perfectly clear, since it is essential that if an adjustment is to be made the action of the mechanism must be thoroughly understood (Fig. 11 is really a combination of Figs. 8 and 9).

HOW THE MECHANISM WORKS

When the record-adjusting knob (Fig. 11) is moved the record jaw adjustment lever moves the jaws outwards for 12-inch records and inwards for 10-inch records, the spring holding it in place (this spring is not present in all models).

How a Record is Played

While the record is being played the motor revolves the turntable and the clutch toothed wheel only.

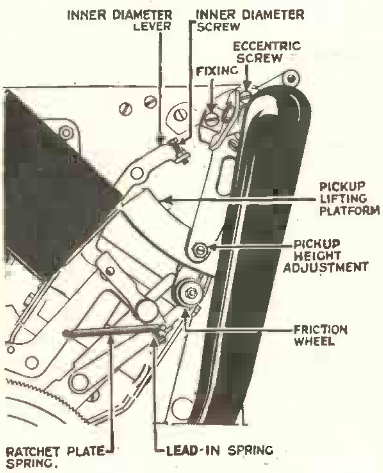


Fig. 10.—A close-up view of the Tone Arm Adjustments.

How the Clutch is Engaged (see Fig. 9)

It will be seen that the clutch consists of two essential parts. The toothed clutch wheel which always revolves with the motor spindle, and the "clutch-engaging lever" which is attached to the clutch plate to which in turn are connected the gear wheels which actuate the cam wheels. When a record is being played the "clutch lever" is prevented from being engaged by its spring with the toothed clutch wheel revolving with the motor spindle and turntable by the tip of the "clutch-trip lever" holding it away from the toothed clutch wheel.

The "clutch-trip lever" is shown in Figs. 1 and 9 just out of contact with the tip of the "clutch-engaging lever," so that the spring has engaged the "clutch-engaging lever" with the toothed clutch wheel, with the result that the "clutch-engaging lever" and clutch plate will now revolve with the toothed clutch wheel on the motor shaft, thus setting the cam wheel in motion. See Fig. 8 (action of record jaws).

The Cam Wheel

This wheel has four cams, two on the top surface and two on the under surface (in some models three) (Fig. 8 does not actually show the two or three cams on the under surface).

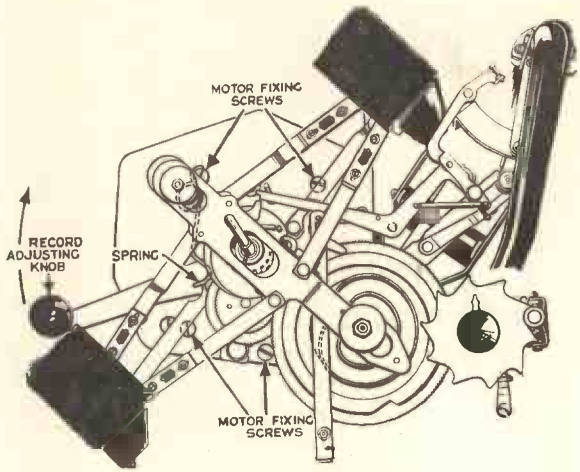


Fig. 11.—The Complete Mechanism.
This diagram is a combination of Figs. 8 and 9.

How the Cams Work

The best plan to describe the correct action of the cam wheel is to describe what happens from the moment that the "clutch lever" (Fig. 9) engages with the toothed clutch wheel and sets the gear wheels in motion. We will show how the clutch can be engaged later.

To study the action of the cams on the "cam wheel," switch off the motor, disconnect the mains, and push the "clutch" lever towards the back of the mechanism so that the tip clears the top of the "clutch lever" and the gear wheels start to revolve when the spindle is turned slightly in a clockwise direction by hand.

Note the "hold-off lever" (Fig. 9) is pushed out of its "recess" and holds the tip of the "clutch-trip lever" out of the way of the "clutch-engaging lever" as it revolves with the motor spindle. Three (or four) cams now come into operation.

(1) The jaw-operating cams.

(2) The "pick-up lifting cam" on underside of the "cam wheel" and the pick-up lifting platform.

(3) The pick-up swinging cam on the underside of the "cam wheel."

The jaw-operating cam (or cams) starts to pull the main links over to the right, slowly withdrawing the lower lips of the record jaws to allow the next record to drop while the upper lips of the jaws slide forward to stop more than one record being dropped.

How the Record Jaws are Worked

Note that to study the movement of the main links and "jaw-operating arms," the "main links" can be moved backwards and forwards by hand. The movement should be perfectly free, there should be no trace of stiffness.

While the cam wheel is moving the record jaws *viâ* the main links and the "dished" cam rings on the top and underside of the "cam wheel," the "pick-up lifting cam" on the underside of the cam wheel starts to depress one end of the "pick-up lifting lever," thus raising the other end of the lever and raising the pick-up head up, so that it can be swung clear of the surface of the record.

Notice the adjusting screw 7 (Fig. 14), which adjusts the lowest amount of pick-up drop.

The "pick-up swinging cam" on the underside of the cam wheel now starts to push the pick-up and arm over to the right out of the way of the record which is about to drop *viâ* the "pick-up arm actuating lever" in Fig. 9 (*x*).

As the "cam wheel" is further revolved this lever now starts to swing the pick-up arm back to the left (the new record having dropped).

The "Lead-in" Spring

Notice that the pressure from the "pick-up arm actuating lever" is transmitted *viâ* the "lead-in" spring No. 9 (Fig. 14).

This spring is most important. Look to see if it is in position and not damaged. Its job is gently to feed the pick-up needle into the first groove of the record when the needle is lowered on to it. If this spring is too strong the needle may jump a groove or two of the record, or if the spring is too weak the needle may not engage with the first groove of the record.

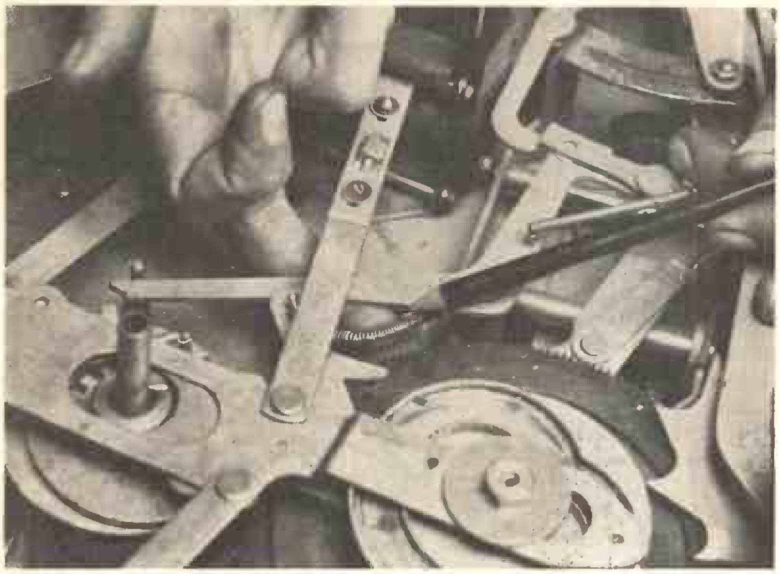


Fig. 12.—The Combined Clutch Trip Lever and Hold-off Lever Spring.

Is the Turntable Level?

This latter trouble may, however, be caused by the turntable and, therefore, the mechanism not being level, with the result that if, for instance, the level is down on the right the lead-in spring may not be strong enough to draw the needle into the first groove of the record because of the weight of the pick-up pulling the other way. The level of the instrument should be tested not on the cabinet, but on the turntable.

The "pick-up lifting cam" on the underside of the cam wheel now allows the "pick-up head" to drop on to the record.

There is another important adjustment to notice here, namely, Screw 6 (Fig. 14).

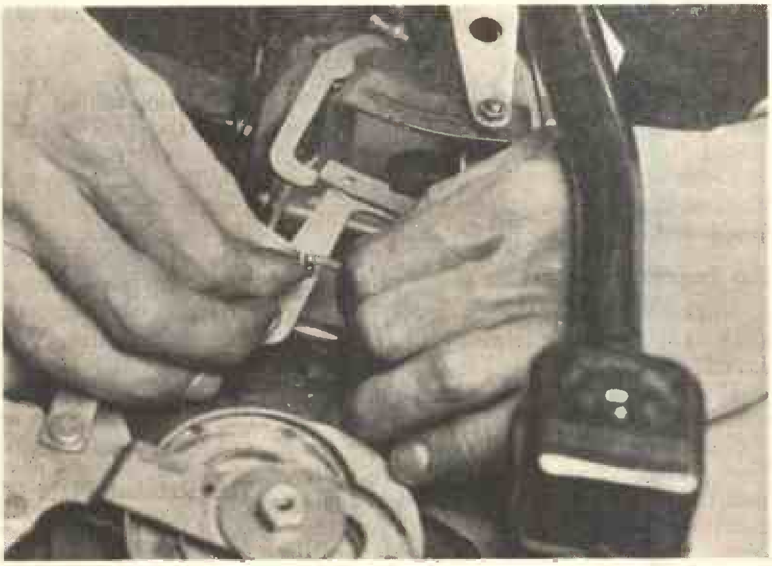


Fig. 13.—Adjusting the Ratchet Plate Spring.

The function of the screw 6, which is eccentric, is to make a slight adjustment of the pick-up head either to the right or to the left so that the needle lands exactly in the middle of the plain part of the edge of the record, the lead-in spring then gently guiding the needle to the left into the first groove. The fixing screw 5 (Fig. 14) must, however, be slacked away before this adjustment can be made.

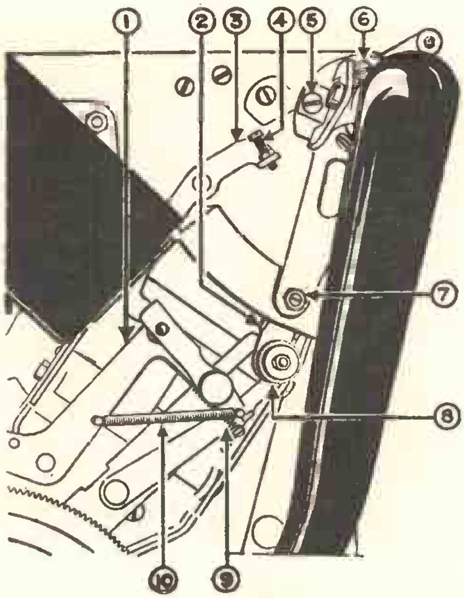


Fig. 14.—THE SPRINGS AND LEVERS FOR AUTOMATICALLY TRIPPING THE CLUTCH ENGAGING LEVER AND STARTING THE CAM WHEEL REVOLVING. (See also Fig. 10.)

How the Clutch is Disengaged

Watch carefully as the cam wheel is rotated further, especially the "hold-off lever" (Fig. 9). As the cam wheel revolves the "toe" of this lever drops into the recess shown in Fig. 9 in main gear, allowing the short arm of the "hold-off lever" to relax the pressure on the "clutch-trip lever" so that the tip of the "clutch-trip lever" catches the tip of the "clutch lever" when it next revolves into position.

The "clutch lever" should be held away from and disengaged from the toothed clutch wheel, thus disconnecting the gear wheels and cam ring and allowing the turntable to revolve and the record to be played.

An Important Adjustment

Notice the "clutch-trip lever" spring (Fig. 12) which operates the hold off lever.

If this spring is weak, absent, or otherwise out of adjustment, the tip of the "clutch-trip lever" will not engage with the "clutch-engaging lever" correctly, and the mechanism would go on changing records without playing them. This may also happen if the "clutch-trip lever" is bent or stiff on its bearing.

How the Clutch can be Engaged

There are three ways of engaging the clutch and setting the record-changing gear wheels and cams in action. The most important is the automatic method operated by the tone arm. The best way to study this is to turn the mechanism so that the motor spindle is running freely, *i.e.*, when the clutch is disengaged and the mechanism is in the record-playing condition.

Now move the pick-up arm this way and that and, referring to Fig. 10, notice first the effect of the "pick-up arm friction wheel" on the "friction wheel ratchet plate," and the way in which the teeth are cut both on the "pick-up arm friction wheel" and the "friction wheel ratchet plate."

How the Friction Wheel Works

When the pick-up arm is moved to the left the shape of these teeth prevent any interaction taking place. This is necessary, since the pick-up arm moves to the left while traversing a record when playing it.

When, however, the pick-up arm moves ever so slightly to the right, as it does in the eccentric grooves at the end of a His Master's Voice record, the teeth on the "pick-up arm friction wheel" and the "friction wheel ratchet plate" immediately engage and the tip of the "clutch-trip lever" is moved away from the tip of the "clutch lever" and the clutch is engaged, setting the cam wheel and record-changing mechanism in operation.

The Ratchet Plate Spring

The action of the "ratchet plate spring" (Figs. 10 and 14) should be carefully noted at this point, for if it is absent or too weak the movement of the "pick-up arm friction wheel" will not be transferred to the clutch mechanism, and the instrument will not automatically change to the next record, but continue swinging about in the eccentric groove at the end of the record.


Fig. 15.—Adjusting the Inner Diameter Trip Lever.

Semi-automatic Tripping

We have now seen how a record having the His Master's Voice eccentric groove can operate the record-changing mechanism, but we must now see how the clutch can be tripped automatically by a record which has no such groove. This is necessary, since a number of makes of records have no such groove, or, if they have, the groove is of the "quick run in" type, which will not give the slight backward movement provided by the His Master's Voice eccentric groove, and which is necessary for the teeth on the wheel and ratchet plate to engage.

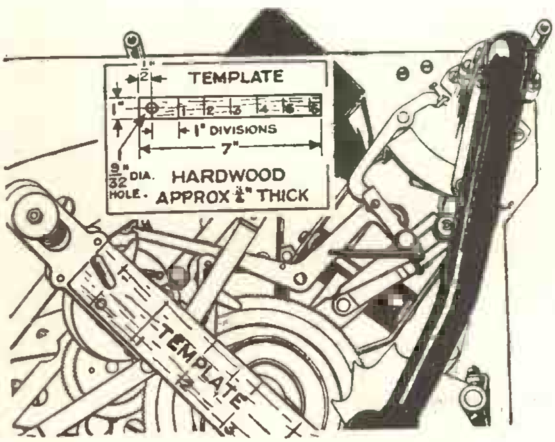


Fig. 15A.—This shows the Template in Position for Setting Inner Diameter Adjusting Screw.

How Non-grooved or "Quick Run In" Records are Changed

This arrangement is shown at 4 on Fig. 14 and on Fig. 9. We have seen that to engage the clutch we have to move the "clutch-trip lever," move the lever 3 about, and notice that when the adjusting screw tip is pushed to the left the other end of the "inner diameter lever" does push the "clutch-trip lever."

If the tone arm is moved sufficiently over to the left it will push the "inner diameter" lever by pressure on the adjusting screw (see top of Fig. 9) and it will set the record-changing mechanism in action by engaging the clutch *viâ* the "clutch-trip lever."

This "inner diameter" lever adjusting screw can therefore be set to start changing a record when the needle has reached a certain "inner diameter" of a record, that is,

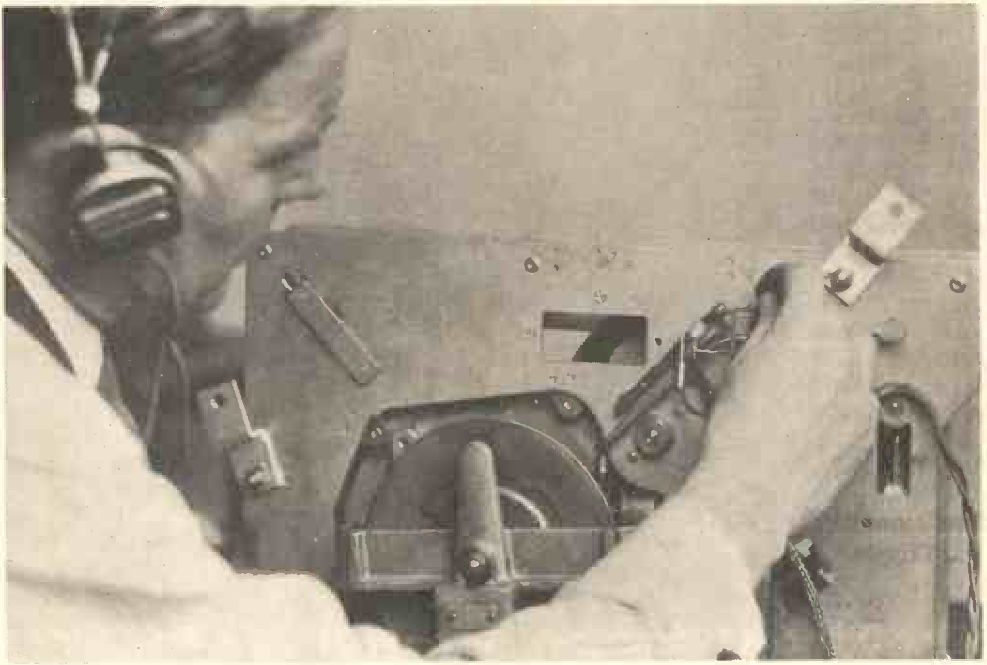


Fig. 16.—LISTENING FOR PICK-UP SIGNAL AT " S.1 " CONTACTS.

it has travelled a prearranged distance to the left.

The Inner Diameter Adjusting Screw

This lever is set by its adjusting screw so that it will be struck by the tone arm when the needle has reached an inner diameter of $3\frac{5}{8}$ inches.

Do not adjust Pick-up Position

It may happen that a slight variation of this is necessary if this is so. The adjusting screw should be altered slightly one way or the other. Do not adjust the pick-up position.

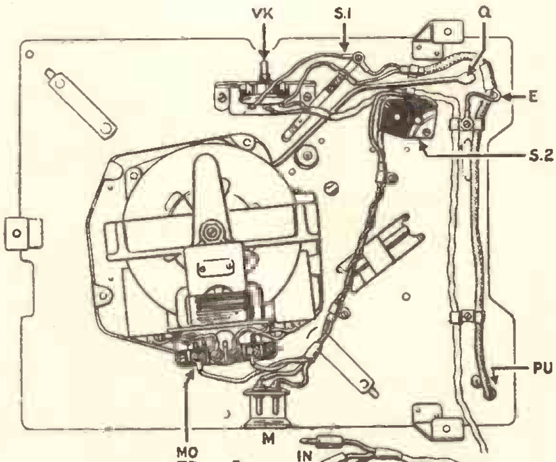


Fig. 16A.—THE MOTOR AND ELECTRICAL CONNECTIONS.

VK, volume control (Mode' 117 Playing Table cnly) ; S.1, pick-up output shoiting contacts ; S.2, motor switch ; Q, speed regulator arm.

The Electrical Equipment (see Fig. 16a)

Nothing has so far been said about the curved-toothed ratched wheel operated by the peg on the cam wheel. It will be seen that this wheel is pushed round one tooth every time a record is changed.

How the Ratchet Switch Wheel Works

This wheel has connected to the lower end of its spindle teeth which engage on a spring lever and on the motor switch respectively. The wheel switches off the motor by releasing the spring lever and switching it on again when it is revolved one further cog.

If it is required, therefore, to switch off after the third record, the wheel is set so that it has to revolve three times before the teeth on the spindle come into action.

If the action of this switch is uncertain, the spring on the steadying lever which presses against the side of the switch wheel spindle should be looked at in relation to the pick-up lifting lever, also the locating roller spring which checks the position of the switch wheel.

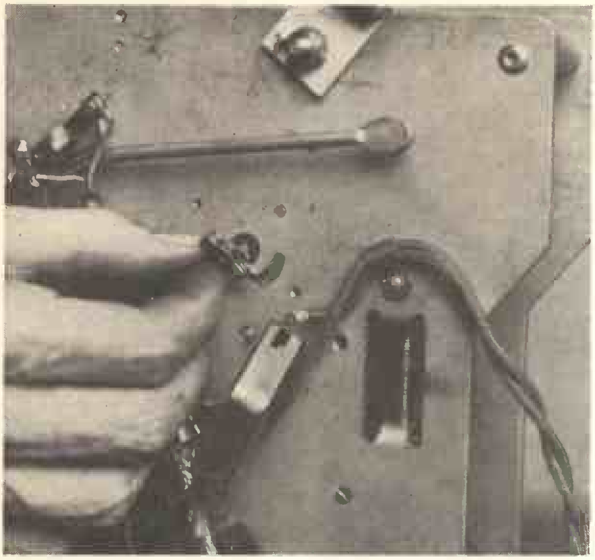


Fig. 17.—Placing Switch Contacts in Position.

How to Check the Motor Circuit (see Fig. 16a)

The mains are fed to the motor by the motor plug, through switch (S.2) and on to the motor terminals. If an avometer is connected to the two pins of the mains plug (M) the continuity of the motor and the correct action of the switch may be checked up. (Note the mains plug may be found on the end of a cord.)

The resistance when the motor is adjusted for voltages of between 200 and 250 volts should be about 75 ohms, and when adjusted for the 100 to 130 volt range about 17 ohms. Any flickering of the needle suggests that the switch may be faulty or that there may be a loose wire somewhere.

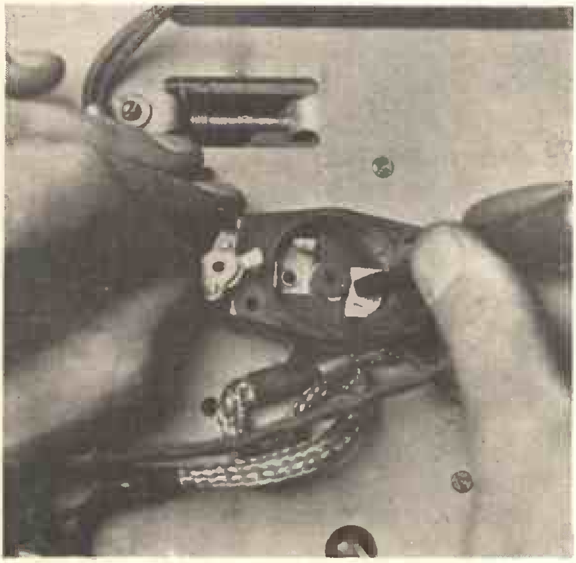


Fig. 18.—Examining Motor Switch.

How to Check up the Pick-up

In certain models of the H.M.V. automechanism a special switch is provided to short circuit out the pick-up just as it touches the record. This switch (S.1, Figs. 16a and 23) is operated by a metal pillar on the underside of the cam wheel which engages with an ebonite plunger.

If this switch remains closed, there will of course be no reproduction from records as the leads from the pick-up coil will be short-circuited. In the case of H.M.V. Model 117 automatic playing table, a volume control (value 250,000 ohms) is also connected in the circuit.

What to Look For if the Pick-up Output appears Faulty

(1) Check the output by a pair of phones. (Fig. 16).

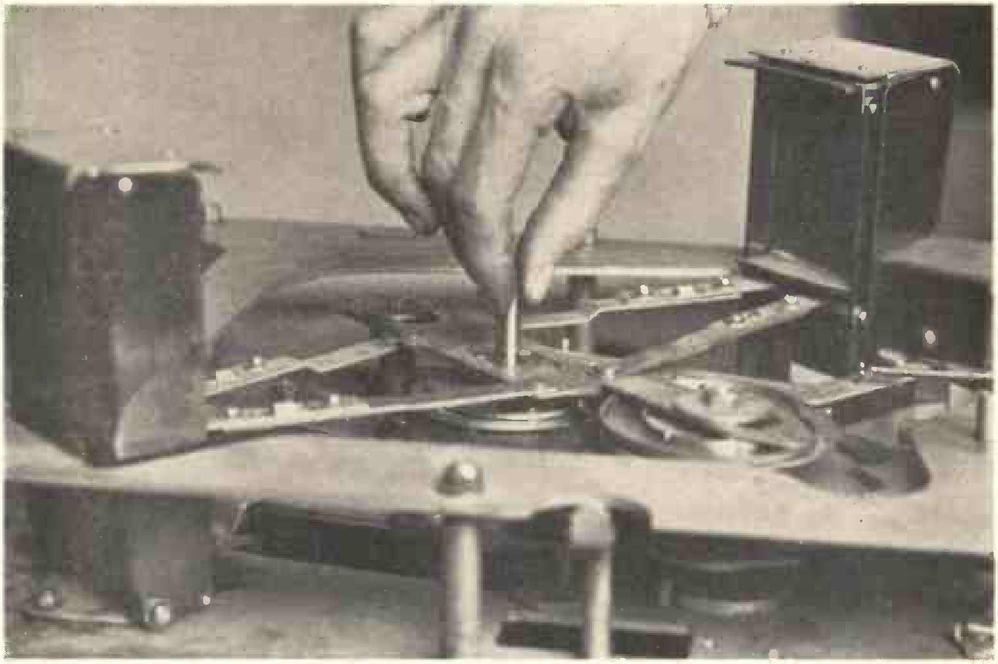


Fig. 19.—TESTING MOTOR SPINDLE FOR FREEDOM.

(2) Check switch S.1 if fitted. (Fig. 23.)

(3) Examine leads inside pick-up by removing head by unscrewing small screw on underside of pick-up arm.

(4) See that metal tags on S.1 are not loose or being touched by, say, the speed regulator arm.

(5) See that no short to earth has occurred *viâ* the metal braiding of the pick-up lead. (Fig. 27).

How to Examine the Motor Switch (S.2)

When examining this switch be careful not to lose any small parts and switch off the current before examining the switch. Turn the switch ratchet wheel in an anti-clockwise direction until the switch is off, *i.e.*, spring lever pushed out of contact with the switch plates and remove the moulded cover of the switch. Be careful not to lose any small fibre washers (if fitted) and note their position for replacement.

See that when the switch is reassembled the small arm on the contactor engages properly on the switch plates on the other side of the mechanism frame.

It will be found easier to replace the switch cover when the switch is in the "OFF" position. See that the rotary contacts are engaging correctly with the fixed contacts and do not attempt to force them to do so. Take the cover off again and reassemble the switch.

A jam may be due to the fibre washers being missing or out of place.

DETAILS OF THE A.C. MOTOR FITTED TO THE AUTO-RECORD CHANGER

Voltage Range

100–130 volts, 200–260 volts; link change over (Fig. 20). 130–160 volts with special condenser of 3 mfds. placed in series with the mains lead to the motor on the motor side of the switch.

IMPORTANT.—In certain instruments the motor will be found connected across terminals 1 and 7 of mains transformer, in which case voltage applied to motor is automatically adjusted to suit the voltage at which the transformer is working.

The motor itself will be found to be adjusted to the 200–260 volt range, AND

THIS ADJUSTMENT MUST NOT BE ALTERED if the motor is connected across the mains transformer of the amplifier or radio unit. To ascertain whether the motor is connected across the transformer, measure the resistance between the motor sockets. This resistance should be 23 ohms if the motor is connected across the transformer and open circuit indicated if connection is to be made direct to mains. *The mains plug must be out when making the test.*

Frequency Range of Standard Motor

40–60 cycles.

Other Frequencies

Special motors are fitted for periodicities of 25 to 33, and of 75–100 cycles.

How the Motor Works

The induction disc type of motor depends for its action upon the eddy currents set up in a plain copper disc so arranged that it will rotate between the poles of two electro-magnets, the windings of one being highly reactive and those of the other being as non-reactive as possible. The combination of fluxes produced by these magnets produces a travelling magnetic field. Interaction between this field and eddy currents induced in disc produced a torque which gives rotary motion to disc spindle and turntable. Governor is driven through worm gearing from turntable spindle.

The Magnet Unit

Consists of :—

(*a*) A laminated steel core held in position by a brass clamping plate and screws.

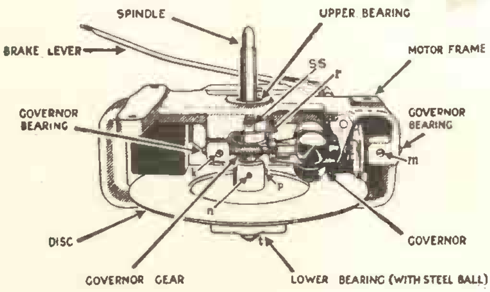


Fig. 20A.—DETAILS OF THE MOTOR.

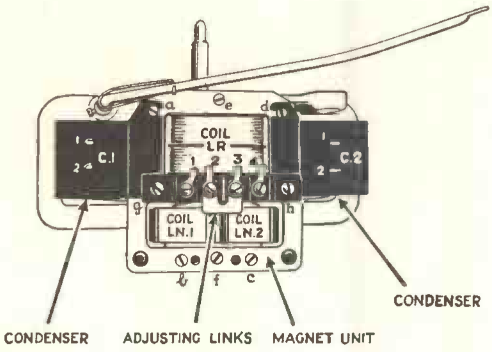


Fig. 20.—THE MAGNET UNIT.

(*b*) One reactive coil LR. Two non-reactive coils LN1 and LN2.

NOTE.—In all cases the inner end of the coil windings terminate in orange wire, the outer windings terminating in yellow wires.

Electrical Data of Coils

D.C. resistance of top section 35 ohms.

D.C. resistance of bottom section 35 ohms.

Lower Coils.—D.C. resistance 1,100 ohms each.

To remove condensers unsolder leads to lugs, slack away screws C1 and C2 respectively (Fig. 20).

Electrical Value of Condensers

2 mfds. each.

NOTE.—In the event of a condenser breaking down, any good make of condenser, Mansbridge type, capacity 2 mfds., may be installed by screwing on the motor-board or other convenient place temporarily, while replacement condensers are being secured.

Warning *re* Removal of Magnet Units

Do not lose conical spacer washer between unit and motor frame. The entire magnetic and electrical units can be withdrawn intact.

NOTE.—It is inadvisable to attempt to rewind coils on this unit.

How to Remove the Governor

Slack off governor and bearing screws, then slide the governor gently towards the movable bearing so that the bearing slips

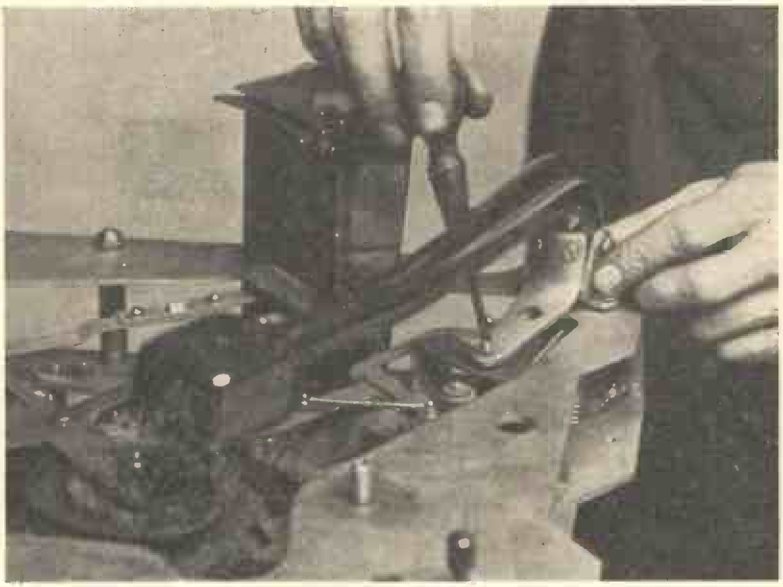


Fig. 21.—Adjusting Height of Pick-up.
This shows screw 7 in Fig. 14 being adjusted.

engages with the bearing screw into which this screw must locate.

This operation should not be undertaken by inexperienced persons, and it is essential that the governor should not be mishandled, or, MORE ESPECIALLY, DROPPED.

sufficiently far to allow the governor to be slipped out of the bearing ; then withdraw governor.

Replacing the Movable Bearing

This bearing is fitted with a slot which

How to Remove the Main Bearing and Induction Disc

(1) Slack away screws securing the disc bush to the spindle.

(2) Slack away the grub screw in the worm wheel hub.

(3) Withdraw the spindle, worm wheel and disc.

Warning

Do not lose steel ball in LOWER MAIN BEARING (*t*) (Fig. 20A).

What the Safety Stop is for

This screw, which secures small metal collar on underside of top bearing, is to prevent inexperienced persons from lifting the whole motor spindle and disc assembly when replacing or removing turn-

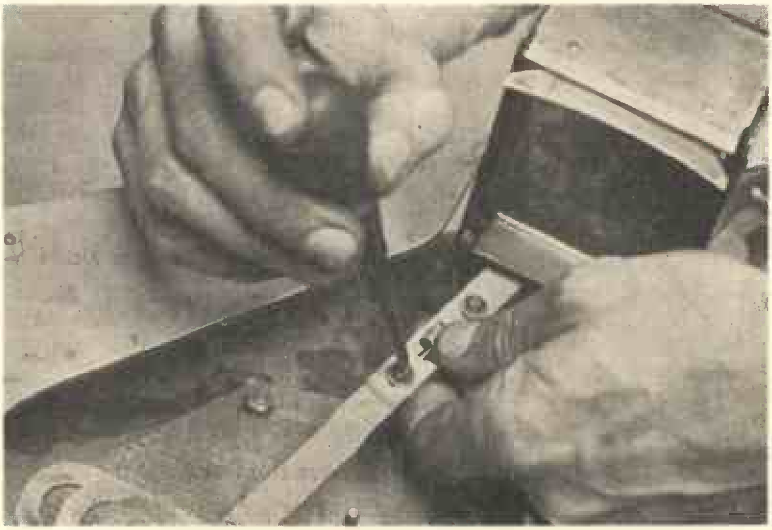


Fig. 22.—Adjustment to Prevent Record Dropping Sideways.
This is screw 15 in Fig. 26.

table and bringing disc in contact with magnet units.

What Oils to Use

It is essential that correct lubricants should be used for this motor. His Master's Voice greases and oils are chosen and carefully tested for freedom from harmful ingredients. It is especially important that the coil on the governor friction pad should be free from acids. For this reason always use His Master's Voice oils and greases.

Renewal of Governor Friction Pad

The clip holding this pad is bifurcated. The pad may be removed by opening the jaws of the clip with a screwdriver, thus loosening the grip on the pad and enabling the new pad to be inserted; when the new pad has been inserted, close up jaws with suitable tool.

How to Reassemble the Motor

(1) See that the steel ball in the lower bearing is present.

(2) See that one grub screw in disc and in main spindle gear wheel are locating in the special "dimples" provided on the spindle.

(3) Adjust the lower bearing screw so that when motor is right way up disc is in correct position in magnet jaws, *i.e.*, does not touch either upper of lower poles.

(4) When lower has been adjusted, adjust the safety screw and collar so that it is impossible to raise spindle and inductor disc assembly so high that the inductor disc strikes the upper magnet pole. Adjust the collar to stop this, but see that the collar is not exercising friction on top of the main spindle gear wheel.

(NOTE.—It is probable that this safety stop screw and collar will not require re-adjusting.)

(5) When replacing the worm wheel the grub screw should be on the top.

The greatest possible care must be taken to see that the inductor disc is not damaged or bent in any way. The disc should be carefully put on one side, after inspection, in a safe place.

A Fault Finding Table for the H.M.V. Motor will be found on p. 253.

HOW TO MAKE ADJUSTMENTS TO THE MECHANISM

What to do if the Pick-up rises too high and touches the Records stacked on the Jaws or does not drop low enough

Before assuming the height of pick-up head is wrong, make certain that the turntable is correctly located upon the turntable pin and IS NOT RIDING UPON PIN.

Having located the turntable, press the button, rotate the turntable in a clockwise direction until the pick-up head drops and the ratchet switch wheel has moved round. In this position the needle should just clear the felt on turntable.

Move the tone arm towards the turntable spindle and, whilst revolving the motor spindle in a clockwise direction, disengage the clutch by giving tone arm a slight backward movement.

When the pick-up is at its maximum height it should just clear the under side of a 10-inch record when the record is resting on the lower plates of the record jaws. The needle point should also rise high enough to clear the top of eight 12-inch records when the pick-up arm is moved towards centre spindle.

If the height of the pick-up is incorrect, adjust by screw 7 (Fig. 14) and fix the screw by locking the nut. (See also Fig. 21).

Examine spring 18 (Fig. 26) and action of catch lever, if necessary strengthening spring 18.

How to prevent more than One Record being dropped at a time or to Adjust a Mechanism which will not drop the Records

If the distance between the top jaw plates is too small, the mechanism will not release the records. On the other hand, if the plates are too far apart, more than one record may be released.

The following operations should be carried out with the spindle in position. Slack off the screws 16 and 29 (Fig. 26) and open the plates to fullest extent. Now, with the current switched off, press the starting lever 26 (Fig. 26) and rotate gears in a clockwise direction until lower record plates are opened to their fullest extent.

Now slack off screws 15 and 31 and adjust lower plates until the largest available 12-inch record just clears the edges. *The lower record plates should release both sides of a record at once* (Fig. 22).

Tighten up screws 15 and 31 to secure this adjustment.

Again rotate gears in a clockwise direction until top separater plates are as far back as possible, and place the largest available 10-inch record on the plates. The separater plates' knife edges should now be set so that they just clear this record.

Secure this adjustment by tightening screws 16 and 29.

The screws fixing the eccentric stops 36 should not be interfered with. These eccentrics only adjust the jaw-adjusting lever in relation to the slots in the metal cover plate.

How to Adjust the Position on the Record where the Needle drops

If the pick-up head drops at the wrong point on either 10-inch or 12-inch records, set the jaws for 10-inch records and slack off the screws 5 (Fig. 14). By turning screw 6 (Figs. 14 and 7) the position of arm for 10-inch records can now be obtained. The needle point should descend in the centre of the plain margin on edge of record. Rotate gears in a clockwise direction and test after making this adjustment.

Now move the jaw-adjusting lever to the 12-inch position and test "drop" of needle on a 12-inch record.

If needle does not drop in centre of plain edge of a 12-inch record rotate gears until pick-up starts to *fall*. DO NOT BRING PICK-UP TO ITS LOWEST POSITION AND DO NOT READJUST SCREW 6. Make a template (shown in Fig. 15A) and place in position shown; the template should be a *tight fit* on the spindle. Carefully mark the distance between the centre of spindle and the needle point. Now set the jaws to accommodate 10-inch records and gently push the pick-up head as far to the right as it will go.

The distance between the centre of spindle and needle point should again be marked on template. The distance between the two marks on the template should be *exactly* 1 *inch*. Should this distance be incorrect, the screw fixing the knurled nut 14 (Fig. 26) should be SLACKED OFF. There is an eccentric on the underside of the knurled nut and the rotary movement necessary is only slight.

Carefully adjust position of knurled nut until this 1 inch difference is secured between the two marks on the template. Check this dimension again *after* tightening the screw fixing the knurled nut.

The correct dropping position of needle on 10-inch records previously obtained should now be checked over, as the adjustment may have altered slightly. THE NEEDLE POINT SHOULD DESCEND ABOUT THREE-THIRTY-SECONDS OF AN INCH FROM THE EXTREME EDGE OF THE RECORD.

Reset the position of arm by screw 6 (Fig. 14), as described previously, and tighten the two screws (Fig. 14).

Readjustment for Records which have not got the His Master's Voice Eccentric Groove

The mechanism is adjusted at the factory to suit records with a finishing groove of $3\frac{5}{8}$ inches diameter, this dimension having been found to cater for the majority of records, including records having no eccentric groove.

If the instrument fails to change the record or does so before the selection has finished, a slight modification of the given dimension should be tried, as the different makers of records tend to vary the point at which their recording groove finishes.

It will be seen that the arm 2 (Fig. 14) pushes the "inner diameter lever" (Fig. 10) when the pick-up is moved over to the centre of the record. This movement of 2 is transmitted to the clutch-trip lever, which in turn releases the clutch lever 12 (Fig. 26, or see Fig. 9.) With the mechanism at rest (*i.e.*, with pick-up arm free to travel towards the turntable spindle), place the template (Fig. 15a) over the spindle and move the tone arm until distance between the needle point and the centre of the turntable spindle is exactly $1\frac{13}{16}$ inches.

Now turn screw 4 (Fig. 14) into contact with arm 2 until trip lever 1 releases the "clutch lever" (Fig. 9) and retighten

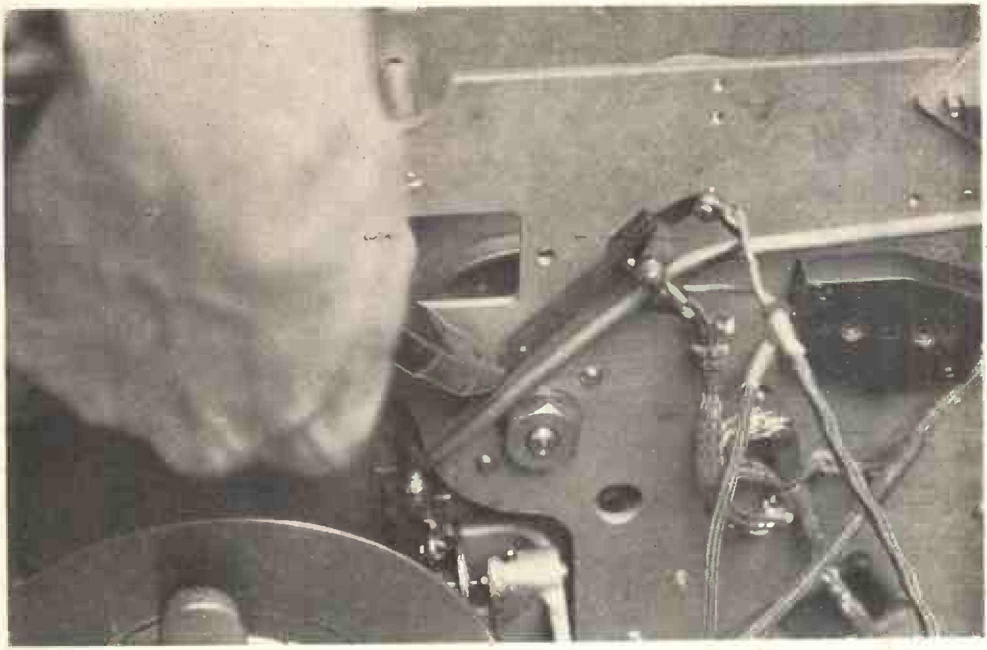


Fig. 23.—ADJUSTING CUT-OUT SWITCH CONTACTS (S.1).

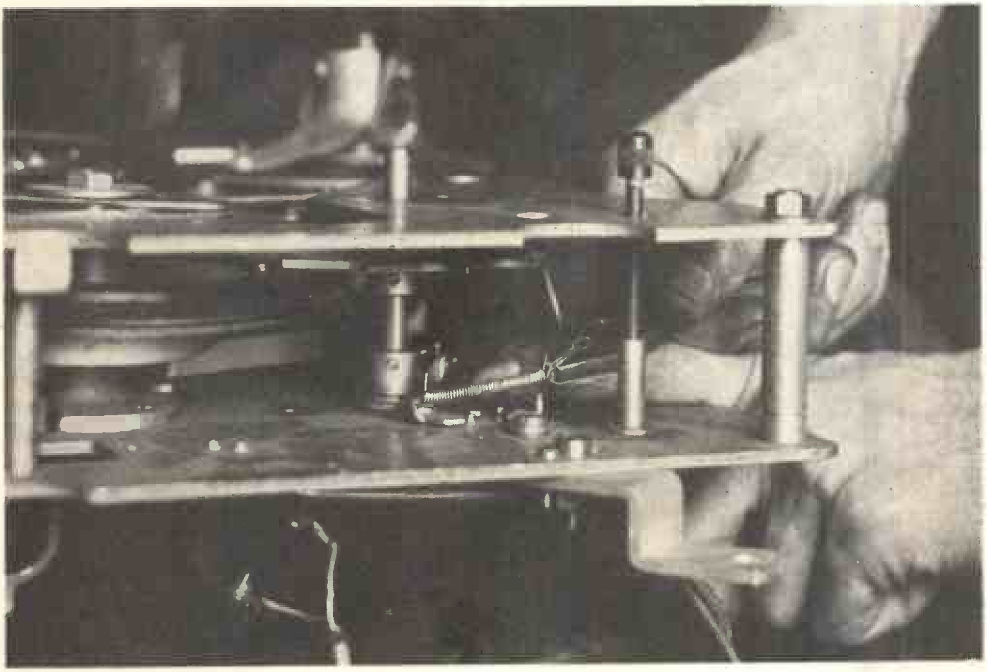


Fig. 24.—ADJUSTING THE MOTOR SWITCH SPRING ARM.

the locking nut on screw 4 to secure the adjustment.

How to Prevent the Needle sliding over the first Two or Three Grooves of the Record

Before touching spring 9 (the lead-in spring) see that the tone arm is moving freely and that the leads from it are clear. Also check up the level of the instrument on the turntable carefully and read the description of the action of the lead spring (9, Fig. 26) carefully on p. 993. If spring 9 is too tight, the needle will jump the first grooves, thus making the pick-up shorting switch appear to open too late. In this connection some records start playing almost on the first groove. Records vary a good deal in this respect.

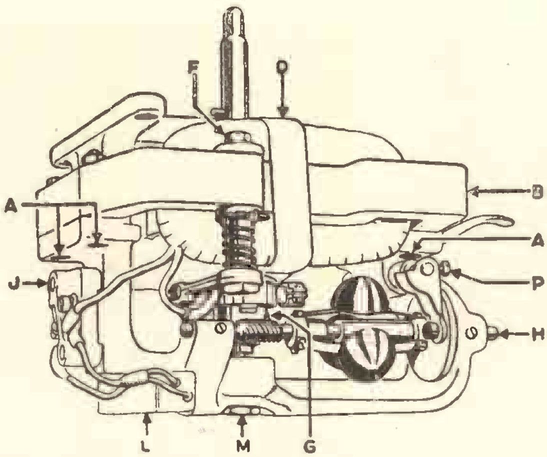


Fig. 25.—The D.C. Motor fitted to His Master's Voice Record Changer.

Note.—If this spring is too tight it will cause the needle to jump the first grooves.

(*c*) See that the tone-arm bearing is perfectly free.

What to do if Records drop sideways

This may be due to :—

(1) Centre of hole of record being worn.

(2) Records with chipped or rough edges.

(3) Bottom rest plates of record jaws not releasing the record simultaneously.

Adjust as follows :—

(*a*) Note which side the majority of records fall first.

(*b*) Taking the back plates as an example, slack off screw 15 (Fig. 26) and make a *very slight adjustment* of the bottom plate *inwards*. Do not make too big an adjustment at once.

What to do if Pick-up will not slide into first Grooves

(*a*) See that instrument is absolutely level, *as tested on turntable*.

(*b*) Very slightly increase tension of spring No. 9 (Fig. 14) *by removing one coil at a time*.

What is probably happening if the Pick-up seems to Strike a Record which is dropping

This is more likely to occur with 10-inch records.

(*a*) Make sure that the record actually *does* touch the pick-up, as the dropping of a record will cause a normal movement of the pick-up transmitted *viâ* the mechanism, though the record does not actually *strike* the pick-up as it falls.

Note.—To test whether this is so, rotate mechanism in a clockwise direction by turntable until the pick-up has swung clear to its fullest extent.

(*b*) Take largest 10-inch record and carefully lower record down spindle WS, watching for clearance between record and pick-up. If the record does actually touch a dropping record it may be that it is necessary to adjust the eccentric screw at the rear of the pick-up arm (6, Fig. 14 and Fig. 7).

Warped records may cause the motor to slow up during the record changing cycle.

If the motor stops while a record is being played and the main voltage is correct with the motor adjustment, examine for mechanical friction somewhere.

How to Prevent the Instrument changing Records without Playing them

The spring which feeds the clutch-tripping lever towards the tip of the clutch lever may be too weak (spring 24, Fig. 26); also read the description of the action of this lever on p. 994.

Cut-out (S.2, Fig. 16a) does not work (Drop of Needle heard in Loud Speaker)

Examine contacts S.1 (Fig. 16a). These should remain *closed* while record is being changed and be *just* separated at end of cycle and remain open while a record is being played. See if stud on underside of gear wheel is correct and firm.

Note.—This is normal if S.1 is not fitted.

Record Sticks in Plates

Try other records to see if due to one or two records only (*unsuitable records*), rough-edged records, warped records, or records with worn centre holes.

Mechanical Clicking Sound while Record is being played

Examine and, if necessary, strengthen spring 24 (Fig. 26), adjusting also, if necessay, spring 27.

HIS MASTER'S VOICE D.C. MOTOR

This voltage-adjusting motor must be used in conjunction with a series resister for voltages of between 50 and 250. Some of the resisters fitted in the instrument have two scales, one marked "MOTOR ONLY" and the other "MOTOR WITH 'K' AUTO." The latter scale should be used.

Electrical Details

Voltage at terminals of motor (motor running), 50 volts.

Current consumption of motor, 0·35 amperes.

Power consumption (motor and resister) on 200-volt mains, 70 watts.

Power consumption (motor and resister) on 250-volt mains, 87 watts.

Resistance of each variable resister tube (measured at ends), 430 ohms each.

Total resistance of resister unit is therefor 860 ohms.

D.C. resistance of each motor field coil, 35 ohms.

D.C. resistance of motor measured at terminal block while armature is slowly rotated, 150 ohms approx. (varies).

Careful watch should be kept for an open circuit, indicated by no reading. This will indicate a burnt-out section. (Headphones and a 2-volt battery can be used.)

To find burnt-out section remove armature and, starting at section with black wire, test on each commutator segment until burnt-out section is located.

How to Remove the Field Coil, Magnet Frame and Armature (see Fig. 25)

(1) Remove the brush gear and levers complete by removing the brush-lever bearing bolts (F).

NOTE.—Do not disturb the insulating bushes and washers on the field frame. Do not lose spring washers and nuts.

(2) Unscrew the orange and yellow leads from the terminal block.

NOTE.—When reconnecting coils to terminal block, correct connections are :—

ONE orange and ONE yellow, the other orange and yellow wire going to the two brush levers.

(3) Temporarily remove spring clips securing the field coil to the frame.

(4) Slide off the field magnet frame complete with the coils.

(5) To remove the coil, remove spring clip and slide off coil from core.

How the Motor is Connected

(1) Current entering the motor by one terminal of motor plug passes by yellow wire to field coil No. 1,

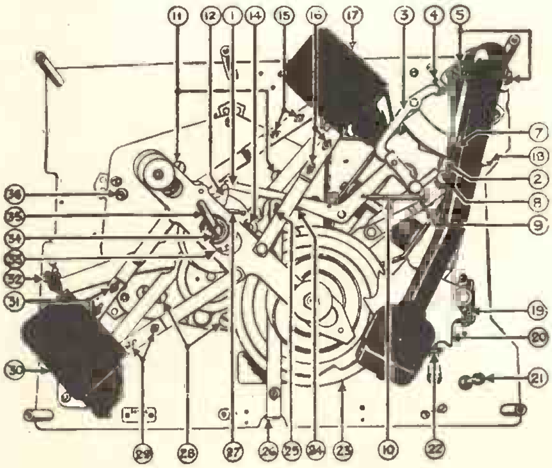


Fig. 26.—INDEX TO THE ADJUSTMENTS ON THE HIS MASTER'S VOICE AUTO RECORD CHANGER.

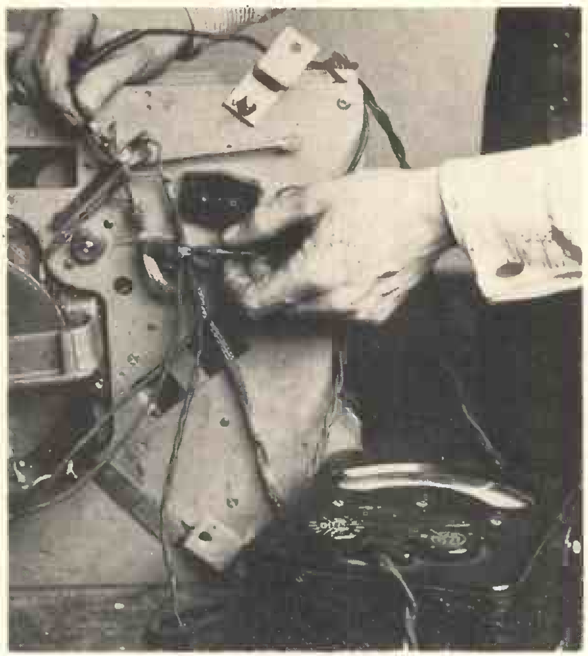


Fig. 27.—CHECKING FOR EARTH BETWEEN PICK-UP LEAD AND SCREENING.

emerging from field coil No. 1 by orange wire and passing the brush No. 1 *viâ* commutator, passes out of armature winding by brush No. 2 and from brush No. 2 by yellow wire into field coil No. 2, emerging from field coil No. 2 and passing to the other terminal of the terminal block by orange wire.

How the Armature can be Removed

(1) Remove magnet unit as before.

(2) Slack off grub screw (G) of governor driving gear and withdraw spindle.

NOTE.—Note "dimple" in shaft when reassembling grub screw and shaft.

(3) Remove armature.

To remove fibre gear from armature, entirely remove grub screw.

D.C. MOTOR FAULT-FINDING TABLE.

Symptom.	Possible Cause.
Motor will not revolve.	Resister unit is burnt out or sliders making bad contact. Mains supply not switched on. Switch operated by cam wheel not functioning correctly. Mechanical jam or undue friction in auto-mechanism on record stuck in jaws. Insufficient or too much brush pressure on armature commutator. Dirty brushes or armature segments (clean with fine glass paper by placing a strip under brush and rotating armature. Do not forget to remove fragments of glass after cleaning).
With signs of over-heating of resister.	Either field or armature coil leaking to motor frame and earth. Short circuit of fixed condenser. The purpose of this condenser is to reduce interference due to sparking between brushes and commutator.
Motor will not revolve after reassembly.	Check up connection of orange and yellow wires.
Motor noisy mechanically.	Lack of or incorrect lubrication. Armature touching field coils. Loose governor spring screws or tight bearings. Bottom bearing of motor not correctly adjusted. Governor and fibre gear not "fairly" engaged.
Motor noisy electrically (*i.e.*, causing interference on Electrical Reproducer).	Sparking between brushes and commutator. Intermittent disconnection, possibly in field coils, between commutator segments and armature section, or on condenser connections. Check all contacts for tightness.
Hum or spluttering in Loud speaker.	Motor frame not correctly earthed. Intermittent leak between armature windings or field windings and earth.
Motor weak.	Dirty brushes. Incorrect voltage adjustment. Insufficient brush pressure. Short circuit in field coil. Lack of lubrication. Undue mechanical friction.

THE GARRARD AUTOMATIC RECORD-CHANGING UNIT

The Garrard Automatic Record-changing Unit will play automatically and consecutively eight 10-inch or eight 12-inch records of any make with usual run-off or eccentric groove.

The motor is a Garrard Induction Electric Motor, which will play on any voltage between 100–130 volts and 200–250 volts, 50–60 cycles. Specially wound models are also available for 40 cycles, 75 cycles and 80–100 cycles. The method of adjusting the motor for either of the two voltage ranges is shown in Figs. 28 and 29.

The speed of rotation of the turntable can be varied between 60–90 revolutions per minute.

Operation

Operation is extremely simple and the method of setting the unit to play either 10-inch or 12-inch records is shown in Fig. 30. When these instructions have been carried out it is only necessary to place the records (any number not exceeding eight) on the platform and turn switch knob to start. The machine will stop automatically when the last record has been played.

"Repeat" or "Reject"

The knob shown on the right in Fig. 30 has two positions, "Repeat" or "Reject," enabling a record to be played again if desired, or rejected. On no account should the pick-up arm be handled for rejecting or repeating a record, as these operations will be carried out correctly and automatically by the adjustment of the knob.

To remove records after playing the centre spindle should be withdrawn.

Fitting the Changer

Two terminals are provided on the main casting to take pick-up leads and two for main leads. It is desirable, although not essential, to "earth" the motor by connecting a wire from the earthing tag fitted under one of the bearing cover screws to some good earth connection, such as an incoming main water pipe.

Fig. 28.—Adjusting the Garrard Motor for 100–130-volt Supply.

Fig. 29.—Adjusting the Garrard Motor for 200–250-volt Supply.

Fig. 30.—How the Garrard Automatic Record Changing Unit is adjusted for either 10-inch or 12-inch Records.

To operate for 10-inch records, lift and turn the three platforms to bring 10-inch mark nearest to table and set pick-up arm at 10 inches.

To operate for 12-inch records, lift and turn the three platforms to bring 12-inch mark nearest to table and set pick-up arm at 12 inches.

The standard " Garrard " pick-up has a resistance of 6,000 ohms, but pick-ups could be supplied specially wound to suit other requirements where necessary. The " Garrard " pick-up head is arranged to swivel 180 degrees so that needles can be inserted with ready facility.

Long playing needles specially made for playing eight to ten records should be used. Several good brands are on the market and can be readily obtained from all gramophone dealers.

Great care should be taken not to strain the pick-up arm by unnecessary handling.

Output of the Pick-up

The output of the " Garrard " pick-up is over 1 volt r.m.s., thus giving ample sensitivity for a 2-valve amplifier.

The lack of very deep bass in the average recording is amply compensated for in the design. The upper register can be reduced if desired, by shunting the pick-up with a fixed resistance of 20,000–50,000 ohms.

D.C. Resistance of coil, 6,000 ohms. Volume control recommended, 100,000 potentiometer.

Maintenance

Maintenance has been reduced to a minimum, the motor bearings being lubricated by three grease cups immediately accessible on removal of turntable. With normal use the grease cups should be given a turn about once a month. The top and bottom main spindle bearings each contain a felt ring saturated in oil which keeps these important bearings lubricated. To re-lubricate it is only necessary to saturate the top bearing lubricating ring with oil about once a month, and the excess oil will find its way down to replenish the bottom bearing felt ring.

The felt pads in the governor regulating brake should also be kept oiled and not allowed to become dry. These pads are easily accessible on removing the name plate from side of motor body.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc.(Lond.)

SECTION XI—THE VALVE—CHARACTERISTICS

THE valve consists essentially of two or more metallic elements enclosed within an evacuated glass bulb. The metallic elements are termed electrodes and one of them is heated to a temperature between 750° C. and 2,000° C. —*i.e.*, to between a dull red glow and white incandescent heat, the particular temperature attained depending on the type of valve and on the material employed in the electrode construction.

The Cathode

The heated electrode is termed the CATHODE, and may be either a filament of wire similar to the filament of an electric lamp, and heated by the passage of an electric current through it, or a metal surface placed very near to a filament and heated by the radiation of heat from the hot filament, the filament being heated as in the former case by the passage of an electric current through it. In the former class are included all the battery type valves, and valves of this class are known as "directly heated cathode" valves. Valves of the second class are known as "indirectly heated cathode" valves.

It will be seen that, in the case of directly heated cathode valves, the terms "filament" and "cathode" are synonymous, whereas in the other case they refer to two distinct parts of the valve structure. The filament of an indirectly heated cathode valve is not counted as a separate electrode, since its function is so intimately bound up with that of the cathode that the two must not be considered apart.

Distinction between Directly and Indirectly Heated Valves

All indirectly heated cathode valves are either A.C. or D.C. mains valves. That is to say, the filaments—or heaters as they are often called—should derive their current from the A.C. or D.C. mains supplies. Not all valves used on A.C. and D.C. mains supplies are of the indirectly heated cathode type, however, a number of directly heated cathode valves being quite suitable for use with mains operated receivers. The distinction between directly and indirectly heated cathode types is one of structural difference rather than of difference of usage.

Effect of Heating the Cathode

The effect of heating the cathode is to cause it to emit electrons. The electrons are "evaporated," as it were, just in the same way as a cloud of water vapour is given off when a quantity of water is heated. The more heat supplied to the cathode—*i.e.*, the higher its temperature—the greater the number of electrons given off by it. The increase in temperature can be brought about by increasing the current through the filament or heater. The explanation of how the electrons come to be emitted by the hot cathode follows directly from the electron theory of matter, and readers who are not familiar with this theory should refer to Ralph Stranger's articles on "Wireless Theory Made Plain." The actual number of electrons emitted by the cathode is in the region of thousands of billions per second. For instance, the cathode of a small power valve ejects something like 40,000,000,000,000,000 electrons per second—*i.e.*, 4×10^{16} electrons per second!

Number of Electrodes

The object of placing other electrodes in the valve is to control and to collect this stream of electrons. The simplest type of valve is that containing two electrodes—a cathode and an anode—and we shall deal with this briefly in order that we may better understand the action of 3-, 4-, and 5-electrode valves. It will be convenient here to point out that valves are often classified according to the number of electrodes they contain, thus :—

Name.	Number of Electrodes.
Diode	2
Triode	3
Tetrode	4
Pentode	5

A diode valve is not manufactured now, except to special order, but a diode effect can be produced by joining together two electrodes of a triode valve. Screened grid and bi-grid valves are tetrodes, and pentode power valves are, of course, familiar to all radio users. A heptode, or 7-electrode transmitting valve was recently produced for use by the British Post Office in some experimental work.

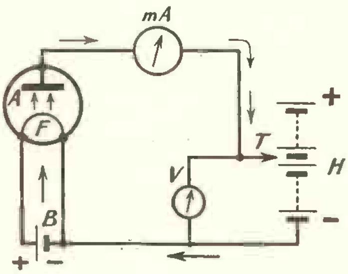


Fig. 1.—A Diode Valve Connected to Two Batteries.

Two Fundamental Facts about Electrons

In considering the action of a valve we shall constantly refer to two important fundamental facts about electrons :—

(1) They are repelled by other electrons, *i.e.*, by negative charges, and by conductors connected to negative ends of batteries.

(2) They are attracted by protons, *i.e.*, by positive charges, and by conductors connected to positive ends of batteries.

The Diode Valve

Fig. 1 shows a diode valve connected to two batteries : F is the filament and B the filament battery, the current from which heats the filament. The electrode A is the anode and is connected, *viâ* the milliameter *m*A, to a battery H, the high-tension (H.T.) battery, so-called because its voltage is generally large compared with that of B, which is often referred to as the low-tension (L.T.) battery. The H.T. voltage used with this valve is variable and may be adjusted by means of the tapping T, and the actual voltage used is indicated by the voltmeter V. As soon as the circuit is completed a current passes through the milliammeter and is indicated by a deflection of the needle.

Effect of Increasing H.T. Voltage

If we were to start with the tapping T at the negative end of the H.T. battery and slowly increase the voltage, we should find that the current indicated by *m*A would steadily increase until a certain value was reached : any increase in H.T. voltage after this value had been reached would not affect the reading of *m*A. In other words, a saturation value is reached, and the current through *m*A cannot be increased above the saturation, or maximum, value.

Increasing the Temperature of the Filament

Now the current indicated by *m*A is due to the electrons from the filament. They are attracted towards the anode because the anode is positive with respect to the filament—it is connected to the positive end of the H.T. battery, the negative end being joined to the filament. As the H.T. voltage is increased the attractive force is increased and so more electrons flow to the anode. Eventually a saturation value is reached, and the anode is attracting all the electrons omitted from the filament. A further increase in H.T. voltage cannot attract more electrons since there are no more available. The only way to increase the number of electrons now is to increase the temperature of the filament, and so to increase the number of available electrons. The direction of the electron stream from filament to anode, through *m*A, and the H.T. battery to the filament is shown by the arrows in Fig. 1.

Characteristic Curves

If we take a series of readings of anode current for different anode voltages we can compile a table of values from which a graph may be drawn. This has been done for a particular valve, and the table and graph are shown in Table I. and Fig. 2. The graph is important and is known as the CHARACTERISTIC CURVE of the valve. If we join together the grid and anode of a 3-electrode valve we produce a diode valve, and such an arrangement would have a characteristic curve of the type shown in Fig. 2. We shall refer to a diode rectifier again in Section XII.

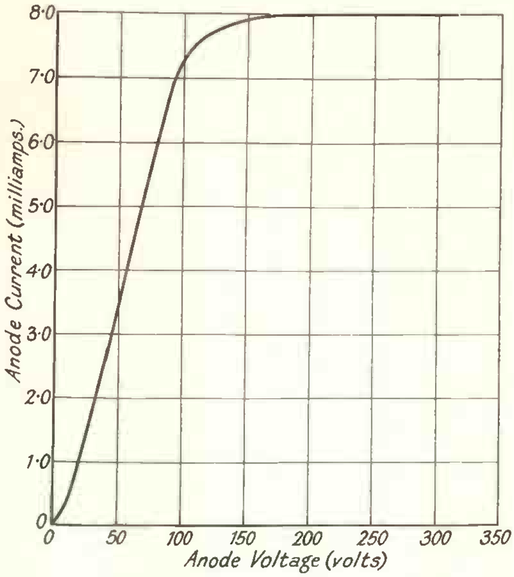


Fig. 2.—GRAPH OBTAINED FROM A SERIES OF READINGS OF ANODE CURRENT FOR DIFFERENT ANODE VOLTAGES.

It is usual to maintain the filament voltage or the filament current at a fixed value with modern valves, and hence in the case of our diode there are only two variable factors, viz., anode voltage (reading of V) and anode current (reading of *m*A).

TABLE I.

Anode Voltage. (V_a) Volts.	Anode Current. (I_a) Milliamps.
0	0
20·0	1·0
27·5	2·0
45·0	3·0
57·0	4·0
68·0	5·0
80·0	6·0
93·0	7·0
107·0	7·5
145·0	7·9
195·0	8·0
225·0	8·0
250·0	8·0
275·0	8·0
300·0	8·0

Three - Electrode Valve

In the case of the 3-electrode valve there are more than two variable factors determining the action of the valve, and more than one characteristic curve can be drawn for any one valve.

The third electrode is the grid situated between the anode and the cathode, and consisting, generally, of a spiral of wire enclosing the cathode. The electron stream from the cathode must pass through the grid spiral on its way to the anode. The grid is connected, *viâ* the external circuit, which may comprise grid-leak or tuning coil, to the negative end of a battery (the grid battery) whose other end is connected to the filament. In certain cases the grid battery is omitted, the grid connection being taken in this case to one side of the filament battery. In Fig. 3 G is the grid, C the grid battery, and V_c a voltmeter which indicates the voltage applied to the grid. This grid voltage is familiar to most radio users as the grid bias voltage. T_c is the tapping on the bias battery enabling the grid bias voltage to be varied.

Grid is Negative with respect to the Filament

It will be seen that the grid is connected to the negative end of the bias battery, and hence the grid is negative with respect to the filament. That is to say, the electron stream will be repelled from the grid; the electrons will not travel around the grid circuit to form a grid current similar to the anode current of the diode valve; in fact, no electrons will pass round the grid circuit—*i.e.*, there will be no grid current. We can show that no grid current exists by connecting a delicate current meter in the grid circuit at X. No deflection will be obtained when the grid voltage lies between about 0 or $-1\frac{1}{2}$ volts and -50 or -60 volts. Grid current can exist under certain conditions of anode and grid voltage, but we need not consider this at present.

The Anode Current

Some of the electrons from the cathode will be repelled by the negative voltage on the grid and will travel back to the filament. A great many, however, will

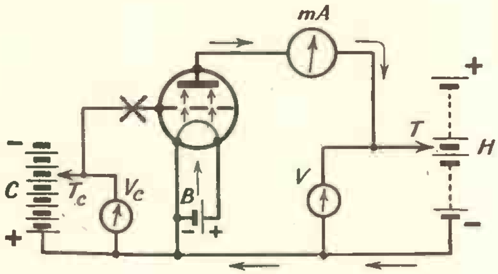


Fig. 3.—CIRCUIT FOR SHOWING CHARACTERISTICS OF A THREE-ELECTRODE VALVE.

pass between the turns of the grid spiral and will then reach the anode, to which they are attracted, as in the case of the diode, by the positive potential of the H.T. battery. These electrons constitute the anode current which passes, *viâ* the milliammeter and the H.T. battery, to the filament, as shown by the arrows in Fig. 3.

Anode Voltage—Anode Current Curves

As in the case of the diode, if we start with T at the negative end of the H.T. battery, and slowly increase the H.T. voltage applied to the anode, the anode current will also increase steadily. In the present case, however, we can do this several times, *each time adjusting* T_c *so that a different value of grid bias voltage is used.* Instead of obtaining one set of corresponding values of anode current and anode voltage, and hence one curve, we shall obtain a different series of values for each grid bias adjustment, and hence a different curve for each value of grid bias voltage. Fig. 4 shows a group of curves obtained by taking anode current and voltage readings for different grid bias adjustments. Such a group of curves is termed a FAMILY of curves, and this particular family is called a family of anode voltage—anode current curves; against each curve of the family it is usual to write the value of the grid bias voltage to which it corresponds.

Grid Voltage—Anode Current Curves

If we now fix T so that a definite value of anode voltage is used, and then vary T_c and note the values of anode current corresponding to different values of grid bias voltage, we shall obtain a series of readings which may be expressed, as before, as a curve. For each position of T we shall obtain a different series of readings, giving a family of curves, one curve for each particular value of anode voltage. Fig. 5 shows such a series of curves, which are known as a family of grid voltage—anode current curves.

Abbreviations Used

We shall use the following shorthand terms when referring to valves and valve curves :—

V_a = anode voltage.
I_a = anode current.
V_g = grid voltage.

The symbol "Δ" (Greek letter Delta) will also be employed in conjunction with these, and then

ΔV_a = a small change in anode voltage.
ΔI_a = a small change in anode current.
ΔV_g = a small change in grid voltage.

When we need to refer to grid current we shall use I_g as shorthand notation. Other terms and symbols will be introduced when required.

A Circuit for Experiments

Let us construct the circuit of Fig. 3 and carry out a few simple experiments with several valves. The values of V_a and V_g will first be adjusted so that $V_a = 100$ volts and $V_g = 0$ volts. Note the value of I_a indicated by the milliammeter *mA*.

Now vary T slightly so that V reads 105 or 110 volts—*i.e.*, so that $V_a = 105$ or 110 volts—keeping V_g fixed at zero volts. Note the new reading of I_a. Now V_a has been increased, and hence more electrons will be attracted towards the anode: that is to say, the anode current (I_a) will be slightly increased. Suppose that when V_a is increased from 100 to 105 volts, I_a for a particular valve increases from 5·5 *m*A to 5·9 *m*A. Now the changes in V_a and I_a are small in comparison with the actual values of V_a and I_a, *i.e.*

$$\Delta V_a = 5\cdot 0 \text{ volts,}$$

and $$\Delta I_a = 0\cdot 4\ mA.$$

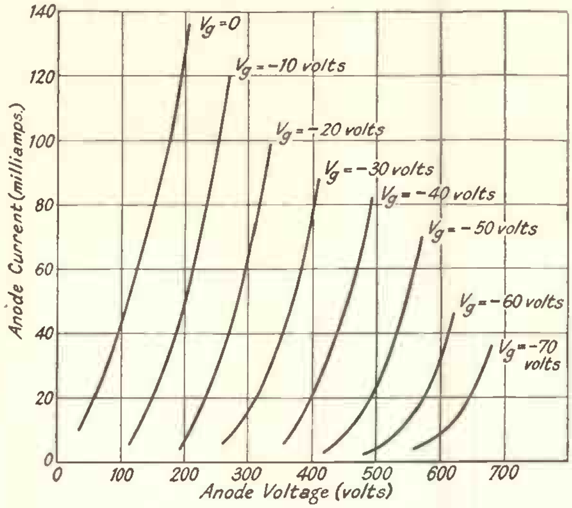


Fig. 4.—A Group of Curves Obtained by Taking Anode Current and Voltage Readings for Different Grid Bias Adjustments.

Differential Anode Resistance

The ratio of ΔV_a to ΔI_a—*i.e.*, the ratio of the change in anode voltage to the corresponding change in anode current—is an important factor in valve theory. The ratio is called the DIFFERENTIAL ANODE RESISTANCE of the valve, and it gets its name in this way: $\frac{\Delta V_a}{\Delta I_a}$ is a voltage divided by a current, and ΔV_a and ΔI_a both refer to an electrical circuit, viz., the circuit through the valve. By Ohm's law a voltage divided by a current is equal to the resistance of the circuit concerned. In this case we are dividing not the total voltage of the circuit, but the difference between two voltages—*i.e.*, the change in voltage—by the difference between the two corresponding currents—*i.e.*, the change in current. Thus the resistance obtained by the division is called the differential (or difference) anode resistance, and R_a is used as a mathematical shorthand for it by most workers. Thus we have:—

$$\frac{\Delta V_a}{\Delta I_a} = R_a \quad . \quad . \quad . \quad (1)$$

In the particular case just cited the change in anode current was measured in milliamperes, whereas, in Ohm's Law, the current must be expressed in amperes when the voltage and resistance are expressed in volts and ohms, hence, expressing ΔI_a in amperes, we have:—

$$\Delta I_a = 0\cdot 4 \div 1{,}000 \text{ amperes,}$$

i.e., $$\Delta I_a = 0\cdot 0004 \text{ amperes,}$$

and $$\frac{\Delta V_a}{\Delta I_a} = \frac{5\cdot 0}{0\cdot 0004} \text{ ohms.}$$

i.e., $$\frac{\Delta V_a}{\Delta I_a} = \frac{50{,}000}{4\cdot 0} \text{ ohms,}$$

or $$R_a = 12{,}500 \text{ ohms.}$$

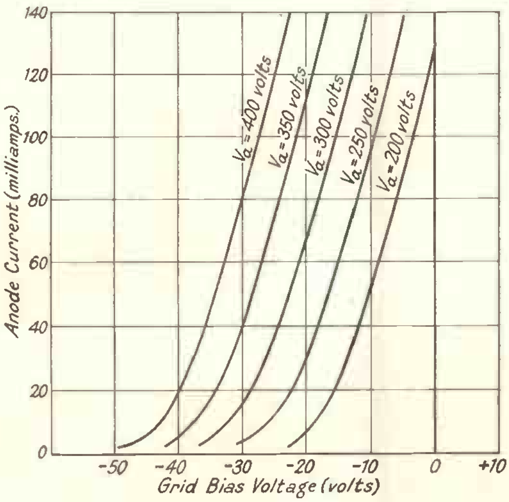


Fig. 5.—A Series of Grid Voltage-Anode Current Curves.

Mutual Conductance

Suppose that now we keep V_a fixed at 100 volts and observe the change in I_a when T_c is adjusted so that V_g changes from 0 to $-1\frac{1}{2}$ volts. Making the grid more negative will obstruct the electron stream by increasing the force of repulsion between the grid and the electrons, hence I_a will decrease. The changes in V_g and I_a are small changes, and will be represented by ΔV_g and ΔI_a. The ratio of these two changes is another important factor in valve theory and is called the MUTUAL CONDUCTANCE of the valve. In America the term SLOPE is used, and this is more exact than the English term. The ratio $\frac{\Delta I_a}{\Delta V_g}$ is actually equal to the slope of the approximately straight portions of the curves in Fig. 5, and for this reason is the more accurate description of the ratio. The shorthand notation used in England is g and in America s. Thus we have :—

$$\frac{\Delta I_a}{\Delta V_g} = g \text{ (English notation)} \quad . \quad . \quad (2)$$

and $$\frac{\Delta I_a}{\Delta V_g} = s \text{ (American notation)} \quad . \quad (2a)$$

An Example

The slope of a valve is measured as the milliamperes change in anode current corresponding to a 1-volt change in grid bias voltage. As an example, suppose that I_a changes from 7·0 to 5·2 *m*A when V_g is changed from 0 to $-1\frac{1}{2}$ volts, then :—

$\Delta I_a = 1{\cdot}8\, m\text{A}.$

and $\Delta V_g = 1{\cdot}5$ volts,

hence $\frac{\Delta I_a}{\Delta V_g} = \frac{1{\cdot}8}{1{\cdot}5}\, m\text{A/volt}.$

i.e., $g(\text{or } s) = 1{\cdot}2\, m\text{A/volt}.$

Amplification Factor

Finally, suppose that we adjust V_a to 100 volts and V_g to zero volts, and note the value of I_a, then adjust V_g to $-1\frac{1}{2}$ volts and move T until I_a comes back to its initial value. Now, making V_g more negative decreases I_a, hence we must increase V_a to counteract the decrease. The changes in V_g and V_a are small and will be represented by ΔV_g and ΔV_a, then the ratio of ΔV_a to ΔV_g is yet a third factor of importance in valve theory. This ratio is called the AMPLIFICATION FACTOR of the valve. The shorthand notation is either m or the Greek letter μ, pronounced "mu," and we shall use m. We have :

$$\frac{\Delta V_a}{\Delta V_g} = -m \quad . \quad . \quad . \quad (3)$$

What the Amplification Factor is

The amplification factor of the valve is the change in anode volts which is equivalent to a 1-volt change in grid bias voltage. Under operating conditions the grid is connected to the source of signal voltage, and the signal voltage (which is, in effect, a small change in grid voltage) produces a corresponding small change of voltage in the anode circuit. Now if the amplification factor of a valve be 12, then a 1-volt change in grid voltage is equivalent to a 12-volt change in anode voltage. This will be dealt with in detail in Section XII.

The Parameters of the Valve

These three factors in valve theory are called the PARAMETERS of the valve, and when they are known for any particular valve its behaviour in a circuit can be predicted, in general. The three factors are connected together by this relation :—

$$1{,}000\, m = gR_a \quad . \quad . \quad . \quad (4)$$

(or $$1{,}000\, m = sR_a \quad . \quad . \quad . \quad (4a)$$)

When two parameters are known (4) enables the third to be calculated. In (4) g (and s) are in milliamperes per volt when R_a is in ohms. In the case of a valve having a differential anode resistance of 12,500 ohms and a slope of 1·2 *m*A/volt, the amplification factor would be :—

$$m = \frac{1{\cdot}2 \times 12{,}500}{1{,}000}$$

i.e., $m = 15{\cdot}0.$

It will be observed that we have taken the small changes in V_a, I_a, and V_g when the actual values of V_a and V_g have been 100 and 0 volts, respectively. Had we taken any other mean, or average, values for V_a and V_g we should have obtained somewhat different numerical answers for each valve on which the measurements were made. To attain uniformity, manufacturers have agreed to rate their valves —*i.e.*, to specify values of R_a, g, and m—at anode and grid voltages of 100 and zero volts, respectively. The values under operating conditions can usually be deduced from the curves supplied.

SERVICING

THE MARCONIPHONE MODEL 535 RADIOGRAMOPHONE

THE Model 535 is a six-valve superheterodyne radio receiver with Marconi Type 14 pick-up, and the Marconi permanent magnet moving-coil loud speaker and Type 24 slow speed Marconi induction disc motor.

The instrument is adjustable for voltages between

95 to 165 volts } 50 to 60
190 to 260 volts } cycles A.C.

If the instrument is worked on a 75 to 100-cycle main a special motor will be found fitted (Type 35D).

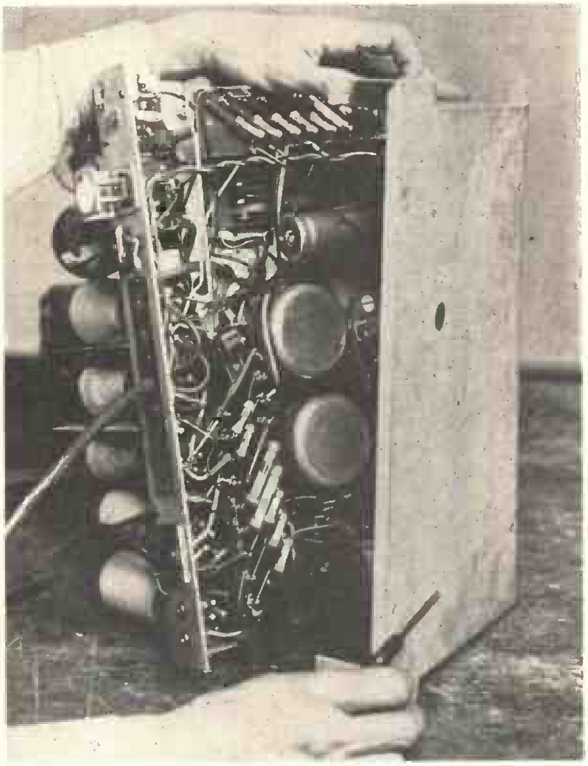


Fig. 1.—REMOVING THE BASE COVER FROM THE MARCONIPHONE 535 RADIOGRAMOPHONE.

Voltage Adjustment

The voltage adjustments are not marked on this instrument for this reason ; in case an instrument is encountered without the instruction book the radio unit voltage adjustments are given below :—

Between	95 and	102 volts	4 and	5
,,	103 ,,	110 ,,	4 ,,	6
,,	111 ,,	118 ,,	3 ,,	5
,,	119 ,,	127 ,,	3 ,,	6
,,	128 ,,	136 ,,	2 ,,	5
,,	137 ,,	145 ,,	2 and	6
,,	146 ,,	155 ,,	1 ,,	5
,,	156 ,,	164 ,,	1 ,,	6
,,	190 ,,	205 ,,	4 ,,	7
,,	206 ,,	222 ,,	3 ,,	7
,,	223 ,,	240 ,,	2 ,,	7
,,	241 ,,	260 ,,	1 ,,	7

General Layout of Radio Unit

The stages of the 535 Radio Unit are as follows :—There is a screened-grid H.F. stage preceding the first detector valve, an oscillator valve, one intermediate frequency amplifier valve, the end detector valve and Marconi PL4 triode power output valve.

Special Note.—In examining this instrument, it must be borne in mind that the mixer valve is coupled to the I.F. amplifier valve by a fixed tuned H.F. transformer tuned to 125 kilocycles and that the intermediate frequency valve is coupled to the second detector valve by a similar arrangement tuned to the same frequency.

The wavelength to which these two

transformers (I.F. T1 and I.F. T2, Figs. 17 and 18) is higher than the usual range of wave meters, and unless a suitable meter is available no attempt should be made to re-trim the trimming condensers TC 1, 2, 3 and 4.

It is exceedingly unlikely that any trouble which has been experienced is due to these condensers, which have been set under special factory apparatus and are visible below holes in the deck of the radio unit close to the ganged condenser. If these have obviously been interfered with it is best to send the instrument back for adjustment.

Fig. 2.—THIS SHOWS THE METHOD OF SETTING THE AERIAL TRIMMER.

the actual position of the coil in the "can."

The Colour Code

The standard Marconiphone colour wiring system is employed, which, it should be noted, is *always the same* in every Marconiphone instrument—this fact has made this system famous and of the utmost value to the service engineer.

How to Find Components Quickly

Figs. 6, 8, 17 and 18 should be compared with the theoretical diagram, Fig. 5.

An examination of these illustrations will show that they indicate at once the exact position of components in the chassis.

Example.—Anode volts are found to be missing on the mixer valve (V3). The coil L11 in the "I.F. T1" is suspected. Fig. 8 shows the position of the "can" in the chassis at a glance, and Fig. 18 shows

How the Circuit Works

(Refer specially to the theoretical diagram, Fig. 5.)

The Aerial Circuit

Signals are fed from the aerial to the aerial tuning coils L1 and L2 (long wave coil) through a small semi-fixed condenser TC5, which should be set when the instrument is installed. Inferior performance may be due to this having been omitted or badly done; the condenser which is situated at the rear of the radio unit (TC, Fig. 7) should have been adjusted with the special insulated screwdriver supplied, for maximum signals when a transmitting station on about 300 metres had been tuned in.

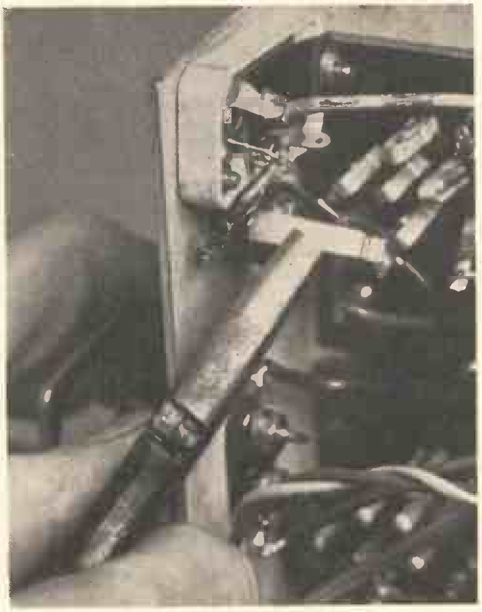


Fig. 3.—ADJUSTING THE MAINS AERIAL JACK.

Note.—A peculi-

IMPORTANT

EDITORIAL ANNOUNCEMENT

DURING the progress of this Work the Editor has received many requests from readers for information on various subjects not included within the original scope of the work.

In addition, many readers have written asking for further articles on :—

Servicing (including Mains Eliminators) and the Baird Televisor.
Wireless Theory Made Plain.
Short Wave Reception.
Constructional Features.

Additional information on Amateur Transmission and Experimental Work has also been requested. A Glossary of Terms, Standard Receiving Circuits (with constructional data), Practical Descriptions of the Blattnerphone (already covered on the theoretical side), Wireless on Trains and Buses are a few other typical suggestions.

In view of the numerous requests received and the variety of subjects suggested for treatment, the Editor feels that he will be meeting the general wishes of readers in expanding the Work to incorporate most of these subjects. He has, therefore, decided to complete the Work in 32 parts, which will permit him to deal with the wide variety of new subjects suggested, thus enhancing the usefulness of the complete Work.

GEORGE NEWNES LTD.,

8-11 SOUTHAMPTON STREET · · LONDON, W.C.2

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SERVICING MARCONI 535

SIMPLICITY THREE-VALVE PORTABLE

DUAL BALANCED LOUD SPEAKERS

DESIGNING A RADIO RECEIVER

1/-

Part 22

IN 32 WEEKLY PARTS

PART 22.

Fig. 4.—MEASURING THE EMISSION OF THE SCREENED-GRID VALVE OF MARCONI 535.

arity common to superheterodynes will be noted with regard to the volume control.

The point when maximum volume is obtained is not necessarily when the volume control has been turned fully clockwise. This phenomenon is quite normal with this type of circuit and must not be mistaken for incorrect performance.

The Aerial Tuning Coils

These two coils (L1 and L2), which are situated on two formers mounted vertically on the top " deck " of the unit, receive the aerial signal from the aerial trimmer condenser (TC5) mentioned before, and pass it on the grid coils of the high-frequency valve by inductive coupling. The coils are tuned by the third bank of the ganged condenser from the right (VC1), the long wave coil L2 being short circuited out of the switch contacts " f " and " e."

How to Understand the Switch Contacts

The Marconiphone Company have introduced a very valuable method of showing, *on the theoretical diagram* (Fig. 5), what every service engineer has had previously to spend a long time tracing, *i.e.*, which contacts should be open in a given switch position, and which should be closed.

The contacts of the switch are shown shaded—on the left of this shading are shown the words " gram," " MW," " LW." If it is desired, for instance, to know which contacts should be closed in the " gram " position, these may be instantly located by the black square which indicates that contacts " m " and " e " are closed, all other contacts remaining open.

Reference to Fig. 8 shows these contacts located on the right-hand side of the front end of the switch contact block. It will be noted that in all cases " e " is earth.

How to Test the Aerial Tuning Coils

Measure between the frame of the radio unit and the fixed vanes of the left-hand section of the ganged condenser looking at the rear of the radio unit (VC1, Fig. 6). The resistance of the " MW " coil (L1) should be approximately 2·7 ohms, and the combined resistances of L1 and L2 (switch in LW position) approximately 23 ohms. If it is necessary to check L2

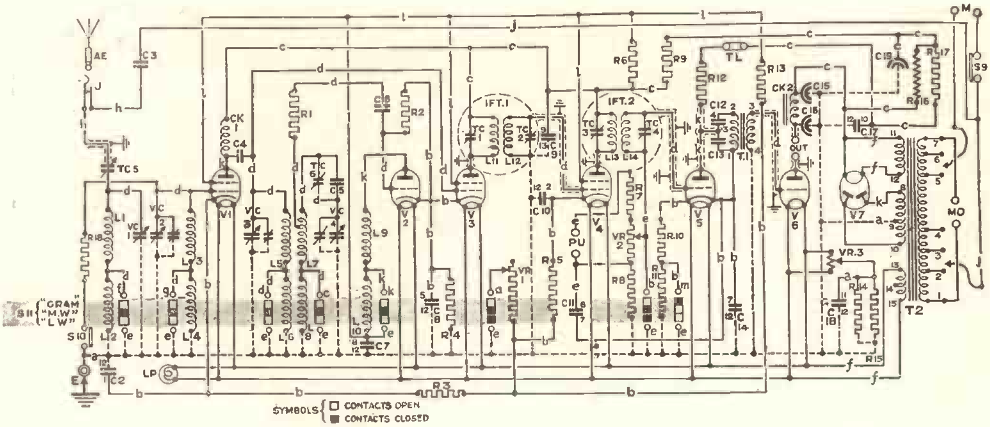


Fig. 5.—THEORETICAL DIAGRAM OF THE MARCONIPHONE 535.

A black square at a switch contact denotes that the contact is closed, *e.g.*, contacts " *a* " and " *e* " are closed in "MW" and " LW" position of the wavechange switch but not for reproduction.

alone measure between the frame of the unit and the sixth contact from the front on the left of the wavechange switch (" f," Fig. 8).

While checking these coils, also check up the wiring to the mains aerial jack (J, Fig. 8).

The Mains Aerial Jack

In many models of the 535 a special aerial plug was supplied. When this plug (AE, Fig. 5) is inserted in the jack (J, Figs. 5 and 8) the contact blades are separated and the main aerial condenser C3 (·0003 mfd.) is disconnected. If, however, the plug connected to the outside aerial is not inserted, the jack contacts close, automatically connecting the mains aerial condenser C3 into circuit employing the electric supply main as an aerial.

The Local - Distant Switch

The other component associated with the aerial coils which should be checked up is the condenser C1 (·005 mfd.). This condenser is switched into circuit as a drainage condenser to earth when the "local-distant" switch is closed, *i.e.*, in the local position.

How the Local-Distant Switch Works

The object of this switch (S10) is to prevent powerful signals swamping the first detector valve by connecting between aerial and earth the fixed ·005 mfd. condenser C1 (sometimes replaced by resistance R18) which by-passes some of the powerful signal to earth. The roller type switch is shown in position in Fig. 8.

Note that an earth on the lead to C1 or in the condenser itself would put the radio side of the 535 out of action. Check this up.

The H.F. Grid Circuit

This circuit consists of the coils L3 and L4 (long wave coil) which are tuned by VC2, the right-hand section of the ganged condenser looking at the back of the radio unit. The long wave coil L4 is shorted out in the "MW" position

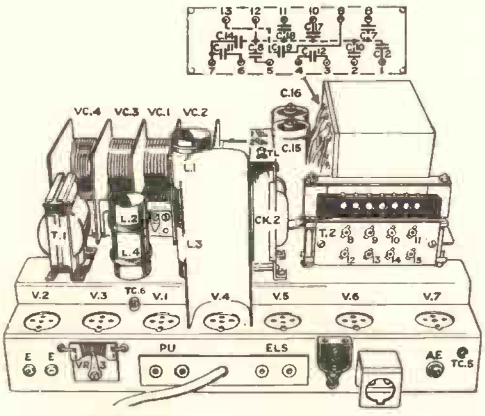


Fig. 6.—THE TOP SECTION OF THE 535 RADIO UNIT.

Showing the internal connections of the condenser can.

by switch contacts "g" and "e." These can be found in Fig. 8.

The H.F. Valve

The signals from this screened-grid valve are choke capacity coupled to the primary windings of the magnetically coupled band-pass circuit between the H.F. valve and the first detector or "mixer" valve. The signal is coupled by the choke CK1 (approximate D.C. resistance 85 ohms) and condenser C4 (·00005 mfd.).

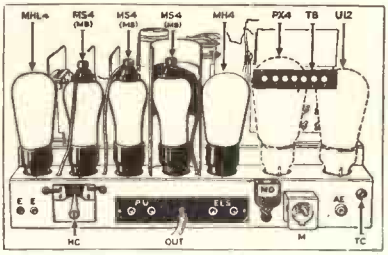


Fig. 7.—The Back of the 535 Radio Unit.

Showing the hum adjusting contact, HC; the motor supply plug, MO; the aerial jack, AE; and the aerial trimmer, TC.

How to Check the Voltages of the H.F. Valve

The anode voltage of this valve is, in common with the anode voltage of the first detector valve and intermediate frequency amplifying valve, obtained from the main high-tension feeder *viâ* the high-frequency choke CK1 situated below the long coil former on the underside of the chassis, the voltage dropping resistance R9 (approximate D.C. resistance, 6,000 ohms), situated on the rack on the underside of the chassis, third from the back (see Fig. 8) and voltage dropping resistance R16 (approximate D.C. resistance, 10,000 ohms).

The voltage should be approximately 215 with the switch in the "gram" position, but with the switch in either "MW" or "LW" positions between 180 and 190 volts with the valve in and measured on an Avometer "1,200 v" scale.

Where to Check the Emission of the S.G. Valve

Insert a milliammeter between the tag and the terminal on the top of the valve. The reading should be about 1·5 milliamperes for "MW" or "LW" positions of the switch, but negligible when the switch is in the "gram" position.

Note. — In checking back for a defective anode voltage supply do not forget condensers C9 and C19 to earth.

Checking the Screen Volts of the H.F. Valve

Measured between the screen socket of the valve and the frame of the radio unit with the valve in and alight, 50 volts is the approximately correct value with the switch in either radio position, although as much as 70 volts may be found with the switch in the "gram" position. The screen milliamperes should be about ·5 of a milliampere with the switch in the radio position, but negligible in "gram" position.

How to Check Back the Voltage Supply to the Screen

It will be noted that the screens at all three screened-grid valves, the "H.F." valve, first detector valve and intermediate frequency valve, are all supplied in common *viâ* the common voltage dropping resistance R6 (approximate D.C. resistance, 25,000 ohms) situated fifth from the left on the resistor rack and running parallel with the valve holders at the rear of the

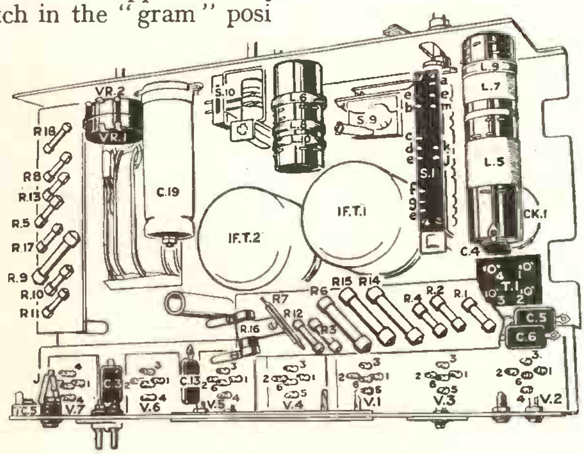


Fig. 8.—How the Components are arranged on the Underside of the Radio Unit.

underside of the radio unit.

C9 and C19 should be examined for breakdown to earth in case of failure of H.T., either to the anode or screen of the H.F. valve.

C9 is of 1 mfd. and situated in the condenser can on the right of the top of the radio unit (see Fig. 6), and is connected to lug 9 of the condenser "can," the other side being connected internally to earth *viâ* lug 13 of the condenser "can."

Fig. 9.—Checking the High-Tension Voltage on the Resistance Rack.

It should be noted that C19, however, is an electrolytic type of condenser (8 mfd.), and that if tested with a milliampere meter for leakage may show a normal leakage current of somewhere about 1 milliampere (measured when all valves except the Marconi "U12" rectifier valve are out).

The Biassing Arrangements for the H.F. Valve

It will be noted that the resistances R3 (D.C. resistance, 900 ohms), situated fourth from the left on the rack near the valve holders, and VR1 lie between the cathode of this valve and earth, and, therefore, *viâ* the coils L3 and L4 to the grid of the valve. R3 therefore provides grid bias to this valve in a similar manner to the R5 for the intermediate frequency valve. It should be noted that if R3 is broken down or disconnected there will be no H.F. anode emission, although anode volts will be present, since R3 and VR1 provide the return path of the anode and screen current to earth and high-tension negative. Note that a breakdown of C2 will by "shorting" R3 take the bias of the H.F. valve, allowing a larger than normal anode current to flow.

Biassing Arrangements for the Oscillator and First Detector Valves

The cathodes of these two are connected together and kept above earth by the resistance R4 (D.C. resistance 2,000 ohms), situated third from the right on the resistance rack near the valve holders in Fig. 8.

How to Check the Bias Resistor for the Oscillator and First Detector Valves

If a resistance measurement is made between either or both the cathode sockets of the oscillator and first detector valveholders to earth, the value of the resistance R4 should be given. If an open circuit is shown, check up the wiring and the resistance itself; if a short is shown, however, suspect the breakdown of the by-pass condenser C8 (·5 mfd.) situated in the "can" on the top deck of the radio unit and connected to lug 5.

How the Second Detector is Biassed

R10 (D.C. resistance, 1,000 ohms), situated second from the back on the rack on the left of Fig. 8, and R11 (D.C. resistance, 5,000 ohms), next to R10 on the same rack, are the bias resistors for the second detector valve.

Note that when the switch is in the gram position that R11 is shorted out by contacts "m" and "e," leaving only R10 in circuit.

This arrangement is provided to decrease the grid bias on the first detector valve when it is operating on a pick-up amplifier valve.

The increased bias provided by R11 in the radio positions of the wavechange

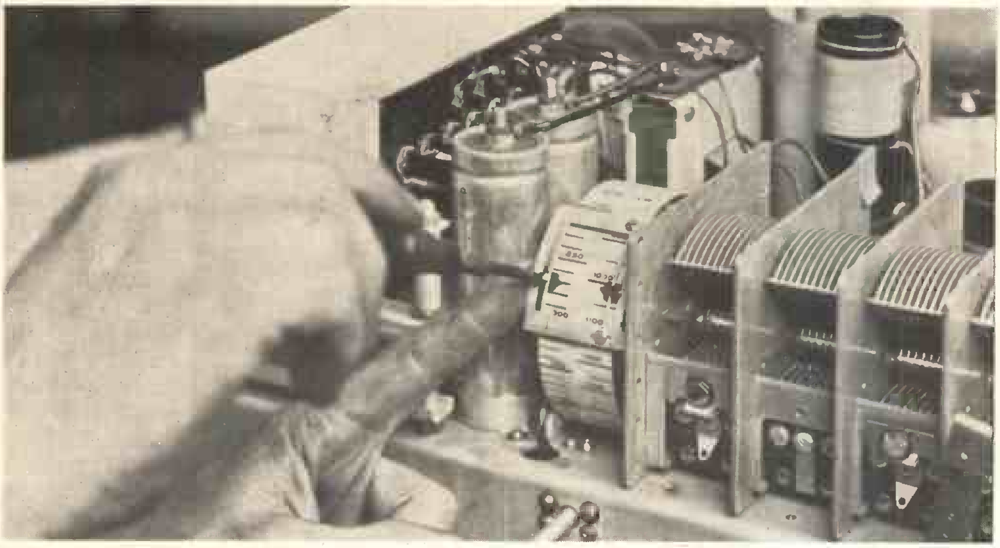


Fig. 10.—How to Set the Scale Pointer.

switch turns the valve into an anode bend rectifier.

The Biassing of the PX4 Output Valve

This valve is directly heated, the filament, therefore, of the valve is separated from earth by the bias resistors R14 and R15 of 2,000 ohms each in parallel, since they have to carry a heavy anode current (about 45 milliamperes). These two resistances, the effective value of which from a bias point of view will be 1,000 ohms, will be found next each other in the centre of the rack shown in Fig. 8 near the valve holders.

Check the decoupling condenser C18 (4 mfd.) also when going through this section of the circuit.

How to Check up the Grid Coils of the First Detector Valve

The coils L5 (medium wave) and L6 (long wave) of the primary of the band-pass circuit between the high-frequency valve V1 and the "mixer" valve V2 can be checked as follows :—

Measure the resistance between the fixed vanes of VC3 (see Fig. 6) and the frame of the radio unit with the wave-change switch in the "MW" position. The reading should be about $2\frac{1}{2}$ ohms.

The long-wave coil (L6) should read about 20 ohms resistance measured between the frame of the radio unit and switch contact "d" of the wavechange switch situated next the long coil former on the underside of the radio unit.

It is important to remember that the wavechange switch must be in the "LW" or "gram" position when this test is made, otherwise the contacts "d" and "e" are closed, thus short-circuiting out the long-wave coil for medium wave operation.

How to Check the Grid Coils of the Oscillator Valve

The same switching arrangement is used for these tuning coils as for the aerial band-pass coils. L8 is the long wave first detector grid coil and L7 the medium wave coil, L8 being short-circuited out by the switch contacts "c" and "e."

VC4, the left-hand section of the ganged condenser looking from the rear of the unit, tunes these two coils ; this condenser should be checked up for dirt between the vanes or an actual short circuit.

It should be noted that all tuning coils terminate to earth so that examination should be made for shorts to earth on any coil tested if a "short" instead of the correct resistance reading is shown.

L7, the medium-wave coil of the oscillator grid circuit may be tested by measuring with an Avometer between one end of the coil and the frame of the radio unit; the D.C. resistance should be about $1\frac{1}{2}$ ohms.

It will be noticed that this coil is "tapped." The continuity of this tap should be checked up also from R1, which is situated on the right-hand end of the resistance rack at the back of the underside of the radio unit.

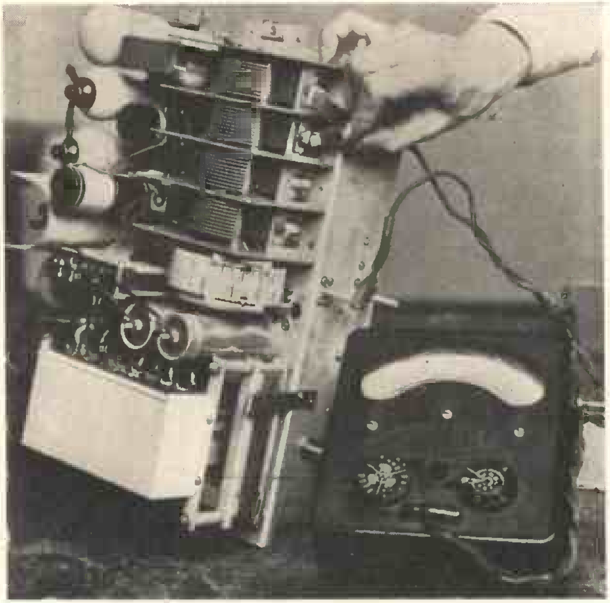


Fig. 11.—CHECKING THE TUNING COIL RESISTANCE.

The Anode Circuit of the Oscillator Valve

The anode voltage of the oscillator valve (V2, Marconi MHL4) is obtained *viâ* the anode coils L9 and L10. It should be noted that while the long-wave coil L10 is shorted out for medium wave operation by the switch contacts "k" and "e," the lower end of these coils is not earthed as in the case of the coils previously dealt with, and that when testing there should be no reading to earth from these coils. If such a reading is found, it may manifest itself by a defective screen voltage on the high-frequency valve (V1), the second detector valve (V2), or the intermediate frequency valve (V4), in addition to almost complete loss of voltage on the anode of the oscillator valve (V3), which receives its anode supply from the same feeder supplying the screens of V1, V3 and V4. Condenser C7 should also be checked up.

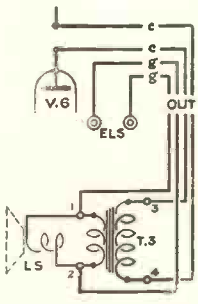


Fig. 12.—THE CONNECTIONS OF THE 535 LOUD SPEAKER CABLE.

Measuring the Oscillator Anode Coils

A resistance test may be made from the anode socket of the oscillator valve (V2) to the switch contact "k" shown in Fig. 8 fourth from the front of the radio unit on the right. This measurement should read approximately 6 ohms, and is the resistance of the medium wave oscillator valve anode coil.

To measure the long wave oscillator anode coil (L10) measure between switch contacts "j" and "k," which should give a reading of approximately 4 ohms.

Note that the wavechange switch should be in the long-wave position, otherwise the switch contacts "j" and "k" will be closed, short-circuiting the coil.

Radio Performance O.K. on One Wave Band only

Such a fault suggests that switch contacts should be examined if, for instance, any one of the pairs of contacts "f" and "e," "g" and "e," "d" and "e," "c" and "e," or "k" and "e" failed to close when the wavechange switch was in the "MW" position one of the long-wave coils would remain in action.

Checking up the Oscillator Valve

If a failure of anode volts is observed on the oscillator valve, condensers to

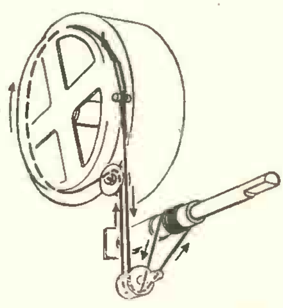


Fig. 13.—THE CORRECT WAY TO REWIND THE CONDENSER DRIVE CORD.

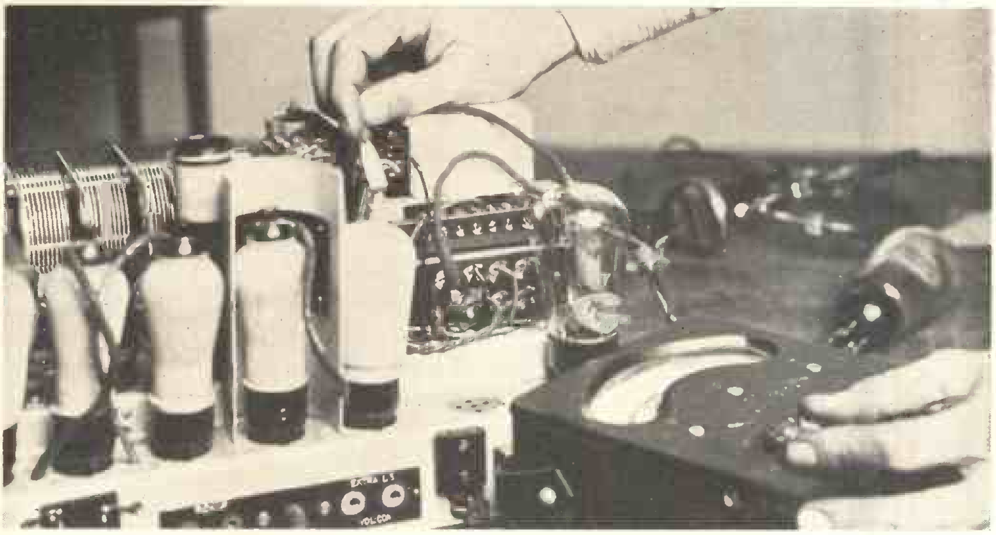


Fig. 14.—Checking the Rectifier Output Voltage from Filament Lead at Rectifier.

earth should be taken into as a possible source of leakage to earth. In addition to this, it will be noted that the switch contacts "j" and "k" are both a high potential above earth and these should also be examined. All leads to the coils L9 and L10 should be examined to see that they are not causing a short to earth anywhere.

The condensers to be noted are C7 (1 mfd.), lug 5 in the condenser "can" mounted at the back on the right of the radio unit top "deck," and C9 (1 mfd.) also contained in the same "can" and connected to lug 9 of the can. C19 is, however, an electrolytic condenser of 8 mfd., and is situated on the underside of the radio chassis between the volume control and the "local distant" switch S10. C7, C9 and C19 are, it will be noted, all connected to earth so that a breakdown of insulation would cause a serious drop in voltage. It should be remembered that if the test of disconnecting the lug of each condenser and interposing a milliammeter is applied, a slight leakage current may be observed through the tubular electrolytic condenser C19. This is normal with this class of condenser.

Resistances in the Oscillator Anode Circuit

R6 (25,000 ohms), situated sixth from the right on the rear resistance rack near the valve holders on the underside of the radio unit; R9 (6,000 ohms), third from the rear on the resistance rack on the left of the underside of the radio unit, and R16, the black wire-wound resistance secured by a metal clip at the left-hand end of the other resistance rack are concerned in the H.T. voltage supply to

Fig. 15.—Checking Smoothing Condensers for Breakdown with Meter inserted in Series.

If the test of disconnecting the lug of each condenser and interposing a milliammeter is applied, a slight leakage current may be observed through the tubular electrolytic condenser.

the oscillator valve, which should be between 50 and 60 volts measured on the "120 v." scale of an Avometer, when the valve is in position and alight.

The voltage will, of course, be higher if measured at the anode socket with the valve out, because no current is flowing except the slight current through the meter. If a confusing failure of H.T. is found the main output of the rectifier can be checked by testing from E to A filament lead of the rectifier valve.

The anode current varies between approximately 5 milliamperes when the wavechange switch is set in the "gram" position to about 3·5 when the wavechange switch is in either of the radio positions, the anode voltage being lower at about 45 volts when the switch is in either of the radio positions.

Fig. 16.—An Intermediate Frequency Can with Cover removed.

The Anode Supply of the Intermediate Amplifier Valve (V4)

This voltage, which should be about 200 volts, measured on the "1,200 v." scale of an Avometer with the valve in and slight, is secured *viâ* voltage dropping resistances R9 and R16 previously dealt with in connection with the anode volts of the oscillator valve and the primary coil of the intermediate frequency. High-frequency transformer "I.F. T1" situated in the round screening "can" next to the wavechange switch.

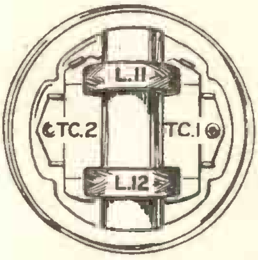


Fig. 17.—The Components of the First Intermediate Transformer.

This coil, like the secondary coil, is tuned by the semi-variable condenser TC1 (see Fig. 17) which tunes the coil to approx. 125 kilocycles at the factory, or a wavelength of about 2,500 metres.

Warning.—These semi-fixed tuning condensers TC1 tuning L11, TC2 tuning L12, the secondary coil of the first intermediate frequency transformer, TC3 tuning the primary coil of the second intermediate frequency transformer, and TC4, the secondary coil of that transformer, should not be touched under any circumstances unless it is evident that they have been tampered with, *i.e.*, sealing compound broken, or one of the coils L11, L12, L13 or L14 have had to be replaced for any reason. The notes, on re-ganging the intermediate transformer, should be very carefully read before attempting the process (see later article).

If no anode volts are found on V4 the coil L13 primary of the first intermediate frequency transformer should be tested by measuring between the anode tag (on end of flexible lead of V4), and the anode tag of V3;

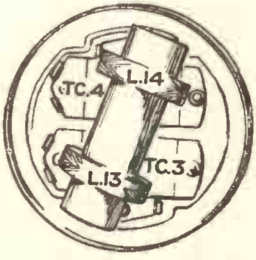


Fig. 18.—The Components of the Second Intermediate Transformer.

the resistance should be about 50 ohms. *See that there is no "short" to the side of the I.F. transformer metal "can".*

A test should also be made to see that there is no "short" to the side of the intermediate frequency transformer metal "can." A glance at the theoretical diagram will show that R9 and R16 are again concerned, and that C9 (1 mfd.) and C19 (the 8 mfd. tubular electrolytic condenser situated on the underside of the radio unit) should be examined.

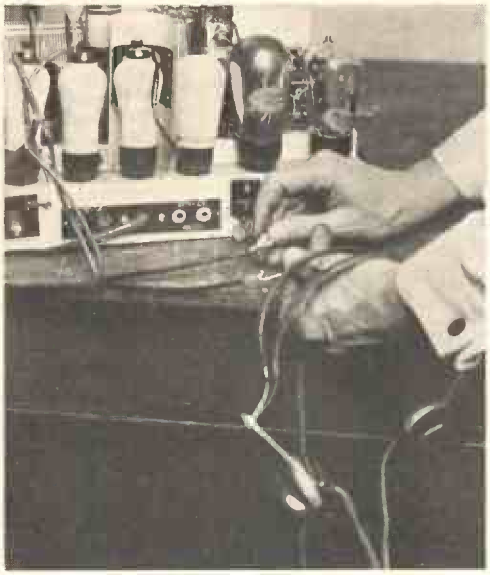


Fig. 19.—CHECKING THE OUTPUT OF THE PX4 VALVE.

The Screen Volts of the First Detector Valve

The screen of the first detector valve obtains its supply in common with the anode of the oscillator valve, and the screens of the high-frequency valve (V1) and the screen of the intermediate frequency valve (V4) *viâ* R6 (25,000 ohms) situated on the rack near the valve holders, see Fig. 8) and R9 which has been dealt with before, the condensers C9 and C19 being again concerned.

The emission of the intermediate frequency valve is about ½ milliampere with the wavechange switch in the "gram" position, but a lower value (from ·1 to ·3 milliampere) with the wavechange switch in either of the radio positions (*i.e.*, medium wave or long wave).

Screen Voltage Very Small

The screen current measured with the valve in is very small indeed; in fact, hardly noticeable at a screen voltage of about 50 volts measured on the "120 v." scale of an Avometer.

Fig. 20.—CHECKING UP THE MAINS TRANSFORMER WINDINGS.

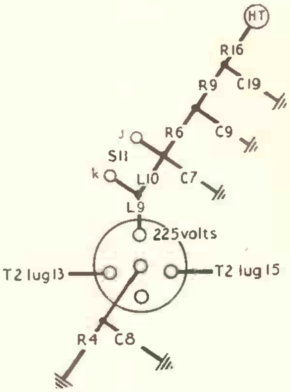


Fig. 21. — RAPID CHECK DIAGRAM FOR OSCILLATOR VALVE HOLDER.

How the Radio Volume Control Works

It will be noticed that a path to earth is provided for the voltage on the H.F. valve screen, oscillator valve anode, and the screens of the intermediate amplifier valve and first detector valve, by the variable resistance VR1 (10,000 ohms), which is mounted on the volume control spindle seen in Fig. 8 between the electrolytic condenser C19 and the resistance rack on the left of the underside of the radio unit.

When this resistance is turned fully clockwise, *i.e.*, to the position of maximum volume and resistance, the leakage path to earth is lowest, the voltage on the anode of the oscillator valve and the screens of the screened grid valve being maintained at such a value that the valves are operating at their full sensitivity.

When, however, VR1 is turned towards its position of minimum volume the value of its resistance decreases and the leakage through it to earth decreases the voltage on the valve anode and screens mentioned above, thus decreasing the sensitivity.

Important Note

With the wavechange switch in either radio position, when measurements are taken, the volume control should be turned to its maximum position, *i.e.*, fully clockwise. If a resistance reading to earth is noticed, it is probably due to the value of V.R.S., and if above 10,000 ohms, need not necessarily be due to a defect somewhere. This point should be borne in mind, and can be checked by moving the volume control when measurements are being made. Note, too, that a failure if C2 (·1 mfd.) situated in the "can" mounted on the top deck of the radio unit —lug 1—"goes down" the voltages mentioned above will be affected; if R3 (900 ohms) is still intact.

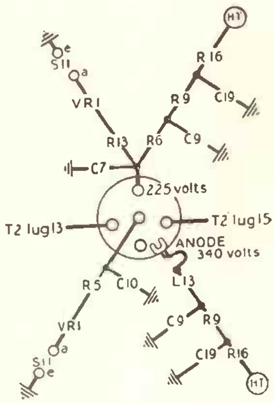


Fig. 22. — COMPONENTS CONNECTED TO THE SOCKETS OF THE FIRST DETECTOR VALVE.

The Intermediate Frequency Valve

The grid circuit of this valve (V4) circuits of the secondary coil of the first intermediate frequency transformer L12 that is tuned to 125 kilocycles by the trimmer condenser TC2, the grid connection being clearly recognisable by the screened lead to the grid of the intermediate frequency amplifying valve.

It should be noted that, unlike L11, the primary coil of the I.F. transformer situated in the anode circuit of the first detector valve L12, the secondary coil is earthed at one end.

How to Test the Grid Coil of the I.F. Valve

A glance at the theoretical diagram shows that a continuity test may be made between the grid socket of the screened grid "I.F." valve and earth (dotted line in Fig. 5). The D.C. resistance of L12 should be approximately 50 ohms.

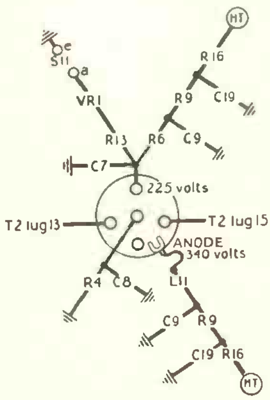


Fig. 23.—RAPID CHECK DIAGRAM FOR THE VALVE HOLDER SOCKETS OF THE HIGH-FREQUENCY VALVE.

How Grid Bias is Provided

To take an example, it will be noted that the grid of the intermediate frequency amplifying valve is earthed *viâ* the secondary coil of the first intermediate frequency transformer (L12) and that high tension negative is also earthed.

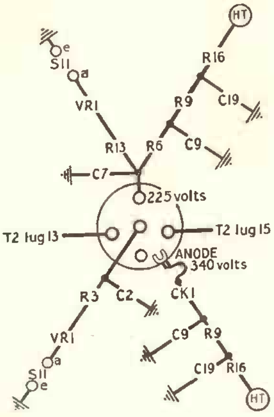


Fig. 24.—COMPONENTS CONNECTED TO THE INTERMEDIATE FREQUENCY VALVE HOLDER.

The current passing through the valve passes from anode to cathode, and *viâ* fixed resistance R5 (900 ohms) mounted on the left-hand resistance rack on the underside of the radio unit (see Fig. 8), and the variable resistance VR1 (10,000 ohms max.) back to earth and high-tension negative.

The cathode therefore is separated from the earth and high-tension negative by the two resistances above mentioned.

Since the valve current is flowing through them there will be a potential difference across them.

Looking at the theoretical diagram (Fig. 5), it will be seen that the top end of VR1 is positive with regard to earth, and that the top end of R5 is more positive still with regard to earth.

The cathode, therefore, which it will be seen is connected to the top end of R5, is positive with regard to earth, and therefore to the grid of the valve which is connected *viâ* the secondary coil of the first intermediate frequency transformer (L12) to earth also.

The grid, therefore, is negative with regard to the cathode, being thus biassed negatively.

How the Radio Volume Control Works

It will be seen that VR1 not only behaves as a bias "voltage dropper" resistance for the intermediate frequency amplifying valve in conjunction with R5, but also for the high-frequency valve (V1), the cathode of both of these valves being kept positive with regard to earth, and therefore negative to their grids in the case of V1 with R3. R3 is of 900 ohms resistance and situated on the resistance rack near the valve holders fourth from the left as seen in Fig. 8.

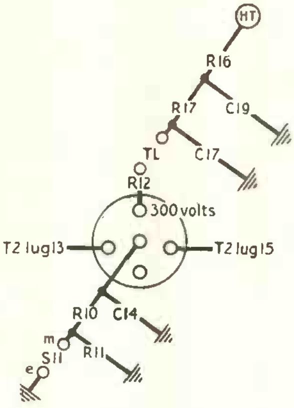


Fig. 25.—COMPONENTS CONNECTED TO THE VALVE SOCKET OF THE SECOND DETECTOR VALVE.

VR1 is variable, and the varying of it will therefore vary the bias on these valves in addition to altering the screen voltages as described before. It should be noted, however, that the circuit which supplies screen voltage to the high-frequency valve, first detector valve, intermediate frequency valve, and the anode of the oscillator valve *viâ* R6 and R9 is also connected to earth *viâ* R13 (50,000 ohms) and VR1. A variation of VR1 will therefore offer a variable path to earth for the above voltages.

When VR1 is at maximum the maximum negative bias is being applied to V1 and V4, and the maximum screen voltage to these valves, and maximum anode voltage to the oscillator valve (V2).

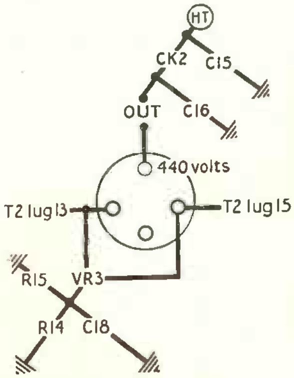


Fig. 26.—COMPONENTS CONNECTED TO THE SOCKETS OF THE POWER OUTPUT VALVE.

When, however, the value of VR1 is reduced, the bias on V1 and V4 is reduced, and a path is offered to the screen voltage circuit to earth, thus reducing the sensitivity of the valves V1 and V4.

The Anode Circuit of the Intermediate Amplifier Valve

High-tension volts are received *viâ* the primary coil of the second intermediate frequency transformer L13, which is tuned by the semi-

WHERE TO MEASURE THE WINDINGS OF THE TRANSFORMER

The Transformer.		Where to Measure.	Correct Resistance.
The Intervalve Transformer	Primary	Tags 1 and 2	1,500 ohms
	Secondary	„ 3 „ 4	5,000 „
The Mains Transformer	Primary	Tag 4 to Tag 5	6·4 „
		„ 4 „ 6	7·1 „
		„ 3 „ 6	7·9 „
		„ 2 „ 6	8·95 „
		„ 1 „ 6	9·8 „
		„ 1 „ 7	23·1 „
	Secondary	„ 11 and 12	0·1 „
		„ 8 „ 9	190 „
		„ 9 „ 10	275 „
		„ 13 „ 15	0·1 „
The Output Transformer (incorporated in Loud Speaker Chassis)	Secondary	Terminals 1 and 2	1·5 „
	Primary	„ 3 „ 4	210 „

variable condenser TC3, resistance R9 (6,000 ohms) and R16 (10,000 ohms). Note condensers C9 (1 mfd.) and C19 (8 mfd. electrolytic to earth) the anode voltage with the valve in should be about 190 volts with the wavechange switch in either MW or LW positions, the emission being in these cases about 1 milliampere.

The switch contacts "a" and "e" are open in the "gram" position breaking the cathode circuit to earth, with the result that there is no emission with the switch in this position. This applies also to the emission of the high-frequency valve (V1).

If a failure of high-tension positive is noted on the anode of the intermediate frequency valve, the condenser C9 should be noted as a possible source of trouble. The value is 1 mfd., and it is situated in the condenser "can" on the top deck of the radio unit (lug 9), the other side being internally connected to the common earth lug—lug 13.

The Screen Volts of the "I.F." Valve

The screen voltage of the intermediate frequency valve is common, as we have seen, to the screens of the high-frequency valve (V1), the screen of the first detector valve (V3), and the anode of the oscillator valve (V2).

Any components which would affect these supplies must therefore be suspected if an irregularity is noted. The screen voltage of the "I.F." valve, which should be about 65, with the switch in "gram" position, and approximately 50 volts with the wavechange switch in either "MW" or "LW" positions, measured on the "120 v." scale of an Avometer, the screen current being about ·4 milliampere.

TABLE OF ELECTRICAL VALUES OF RESISTANCES

R1	Fixed resistance	5,000 ohms
R2	„ „	25,000 „
R3	„ „	900 „
R4	„ „	2,000 „
R5	„ „	900 „
R6	„ „	25,000 „
R7	„ „	150,000 „
R8	„ „	100,000 „
R9	„ „	6,000 „
R10	„ „	1,000 „
R11	„ „	5,000 „
R12	„ „	50,000 „
R13	„ „	50,000 „
R14	„ „	2,000 „
R15	„ „	2,000 „
R16	„ „	10,000 „
R17	„ „	7,000 „
R18	„ „ (When fitted)	2,000 „

WHERE TO MEASURE THE RESISTANCES OF THE TUNING COILS

The Coil to be Measured.	Set the wave-change Switch for.	The Correct Resistance.	Where to Measure.	
L1 . .	" M.W."	2·7 ohms	Measure between stator of VC1 and frame (EARTH)	TOP SIDE OF CHASSIS
L3 . .	" M.W."	2·7 ,,	Measure between stator of VC2 and frame (EARTH)	
L5 . .	" M.W."	2·7 ,,	Measure between stator of VC3 and frame (EARTH)	
L7 . .	" M.W."	2·6 ,,	Measure between one end of L7 and frame (EARTH) resistance between centre point of this coil and EARTH should be 1·6 ohms	UNDERSIDE OF CHASSIS
L2 . .	" L.W."	20 ,,	Measure between contact (f) (S11) and frame (EARTH)	
L4 . .	" L.W."	20 ,,	Measure between contact (g) (S11) and frame (EARTH)	
L6 . .	" L.W."	20 ,,	Measure between contact (d) (S11) and frame (EARTH)	
L8 . .	" L.W."	11 ,,	Measure between contact (c) (S11) and frame (EARTH)	
L10 . .	" L.W."	4 ,,	Measure between contacts (j) and (k) (S11)	
L9 . .	" M.W."	6 ,,	Measure between contact (k) (S11) and anode socket of V2	
L11 } I.F.T1		50 ,, approx.	Measured at ends of coils	
L12		50 ,, ,,		
L13 } I.F.T2		50 ,, ,,		
L14		50 ,, ,,		
CK1 . .		85 ,,	Measure across ends of choke.	

How the Loud Speaker is Connected to the Radio Unit (see Fig. 12)

The coupling transformer of the 535 loud speaker is attached to the loud speaker unit and not contained in the radio unit. The primary of this transformer is connected directly in the anode circuit of the output power valve by the two red wires. The emission of the power valve may therefore be tested by disconnecting one of the red wires and inserting a milliampere meter. The reading should be approximately 45 milliamperes. Loud signals will be heard here, but if checked on headphones they should not be worn on the head.

How to Check the Output Transformer

The continuity of the output transformer primary may be checked by connecting an Avometer set to the " 1,000 ohm " scale to the two red wires or across lugs 3 and 4 of the transformer. The resistance should be about 210 ohms.

The secondary winding of the transformer should be about 1½ ohms, and can be measured across lugs 1 and 2. It should be remembered, however, that the coil of the loud speaker itself should be disconnected when doing this, otherwise a reading of between 9 and 10 ohms may be obtained—the resistance of the loud speaker speech coil—even if the secondary winding of the loud speaker coupling transformer is burnt out.

How the Extra Loud Speaker Sockets are Connected (E.L.S., Fig. 6)

The two pink wires in the cable are those which connect the secondary winding back to the extra loud speaker sockets on the radio chassis. These have been connected to the low-resistance winding of the loud speaker coupling transformer so that a low resistance moving coil loud speaker may be directly connected to the extra loud speaker sockets without the need of a coupling transformer.

TABLE OF ELECTRICAL VALUES OF FIXED CONDENSERS

C1	Fixed Condenser	·005 mfd.	
C3	,, ,,	·0003 ,,	
C4	,, ,,	·00005 ,,	
C5	,, ,,	·002 ,,	
C6	,, ,, (When fitted)	·0003 ,,	
	Screw securing condenser block		
	Nut for above screw		
	Shakeproof washer		
C13	Fixed condenser	·002 mfd.	
C15	,, ,,	8· mfd. electrolytic	
C16	,, ,,	8· ,, ,,	
	Screw securing C15, C16, C19		
	Nut for above screw		
C2	Fixed Condenser	·1 mfd	in " can "
C7	,, ,,	1·0 ,,	in " can "
C8	,, ,,	·5 ,,	in " can "
C9	,, ,,	1·0 ,,	in " can "
C10	,, ,,	·1 ,,	in " can "
C11	,, ,,	·5 ,,	in " can "
C12	,, ,,	·1 ,,	in " can "
C14	,, ,,	·5 ,,	in " can "
C17	,, ,,	1·0 ,,	in " can "
C18	,, ,,	4·0 ,,	in " can "
C19	,, ,,	8·0 ,, electrolytic	

How to Connect a High-Resistance Loud Speaker to the 535

Although this is not recommended from a quality point of view, this can be done by connecting the additional high-resistance loud speaker to the lugs 3 and 4 of the loud speaker coupling transformer. This puts the high-resistance loud speaker in parallel with the primary of the output transformer.

Any wiring to an additional high resistance loud speaker should be well insulated, as a glance at the theoretical diagram will show that this wiring will be about 300 volts D.C. above earth. Damp or exposed wiring might therefore cause a serious leakage of high tension apart from a risk of shock.

How to Replace a Condenser Drive Cord (see Fig. 13)

(1) Remove the four screws fixing the local-distant switch (S10) and move the switch as far as the wiring will permit.

(2) Procure a piece of flax fishing line having a breaking strain of approximately 40 lb.

(3) The approximate length for one instrument is 27 inches.

(4) Double back 1 inch of the cord and tie a knot so that a loop in the end is formed.

(5) Fully disengage the condenser vanes and turn the tuning control spindle as far as possible in an anti-clockwise direction.

(6) Put the loop end of the cord over the small stud on the condenser drum and wind the cord in the direction indicated by the arrows.

Use a Stiff Piece of Copper Wire

A STIFF PIECE OF COPPER WIRE WITH A HOOKED END WILL BE FOUND USEFUL IN MANIPULATING THE CORD.

There should be six complete turns on the tuning control spindle, which should not overlap one another.

Keep the Tuning Control Spindle in Anti-clockwise Stop Position

IMPORTANT.—The tuning control spindle must be kept to its anti-clockwise *stop* position while the cord is being wound on.

(7) Pull the cord tight, doubling back 1 inch, tie a knot so that a loop is formed on the end. The loop end should be made so that the coils of the tension spring are opened when the spring is assembled on to the stud. In this way a constant tension is exerted in the cord.

By following out the detailed instructions given above, no difficulty should be experienced in replacing a condenser drive cord.

THE "SIMPLICITY" THREE-VALVE PORTABLE

By FRANK PRESTON

THERE is an increasing demand for portable sets of the simplest type which will give good reception of the local Regional and National Transmitters without the use of an outside aerial. Until fairly recently even the most simple portables were more or less costly to build and they were expensive to run, due to their heavy drain on both high- and low-tension batteries. Because of the two facts just mentioned, the "Simplicity" portable, which is described here, will meet with general approval. It nicely fills the gap between expensive portables intended for long-range reception and cheap receivers of the "fixed" type, which require a good aerial for their correct functioning.

Fig. 1.—THE "SIMPLICITY" THREE-VALVE PORTABLE READY FOR USE.

Some Points About the Set

Before going further it might be advisable to point out just what the present set will do and what it will cost to make. The "Simplicity" has been designed essentially as a "local" receiver; in its present form it will *not* give good reception of distant stations. But it *will* supply good quality loud speaker signals from two or three stations when used in any part of the country. The volume is sufficient to fill any average sized drawing-room or to afford enjoyable listening in the open air.

Selectivity

Selectivity is of a very high order so that the elimination of the nearest station will present no difficulty whatever. Since the total weight of the set is only about 25 lb. it can be carried over short distances without very great effort and can certainly be moved from room to room by any female member of the household. Moreover, the containing case is not bulky, measuring, in fact, $13\frac{3}{4}$ by $15\frac{3}{4}$ by $9\frac{1}{4}$ inches.

Easy Tuning

Tuning is a very simple matter, being carried out by means of a single knob, and even though the reaction condenser must be used to obtain best results its operation is not difficult, even for one who has never handled a receiver before.

Low Cost

The whole receiver, including cabinet, batteries, valves and loud speaker costs less than £8, or no more than a medium-priced receiver of the ordinary kind.

Low Running Costs

Running costs are proportionally low, for the consumption of high-tension current is rather less than 7 milliamps, and of low tension, ·6 ampere. In other words, the high-tension battery (which costs only 10*s*. to replace, by the way) will have a useful life of from four months upwards, whilst the 24 ampere-hour accumulator will give about forty hours' service per charge.

Simple Construction

To the above advantages must be added that of easy construction. The cabinet specified has been specially made up to the design of the writer and similar ones are now avilable to the public already fitted with a wooden chassis for the receiver proper, a winding frame for the aerial, and supplied with a length of leatheroid braid through which all leads to the frame aerial and loud speaker can be passed. In addition, the speaker fret is already drilled to take the two mounting screws for the loud speaker unit. As a result, the building of the receiver is quite in keeping with the name it has been given.

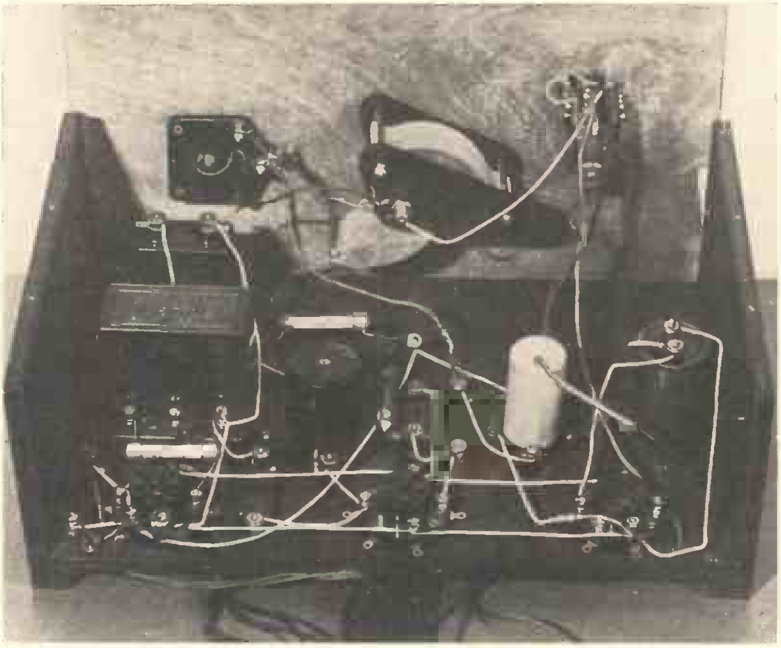


Fig. 2.—THIS SHOWS THE NEAT MANNER IN WHICH THE WIRING IS ARRANGED.

The panel has been removed and one wire (from the grid of the screened-grid valve to tuning condensers) has been disconnected.

The Circuit

The circuit is shown diagrammatically in Fig. 4, and here again simplicity is the keynote. I will not say that the circuit is new or even particularly original; it is neither, but it comprises the best of all those well-tried features which have stood the test of time. Even so, it is not old-fashioned and uses the combination of valve stages most popular at the present moment, namely, Screened Grid-Detector-Pentode.

Let us examine the circuit in detail, beginning at the frame aerial end. The frame has two windings, one of which is tuned by a ·0005 mfd. condenser, whilst the other is used to provide reaction or feed-back between the anode and grid circuits of the S.G. valve. The tuned winding is tapped to provide long and medium wave reception, the long-wave portion being short-circuited when desired by means of a double-pole-double-throw switch, which also serves to connect and disconnect the battery supply. The S.G. and detector valves are coupled together

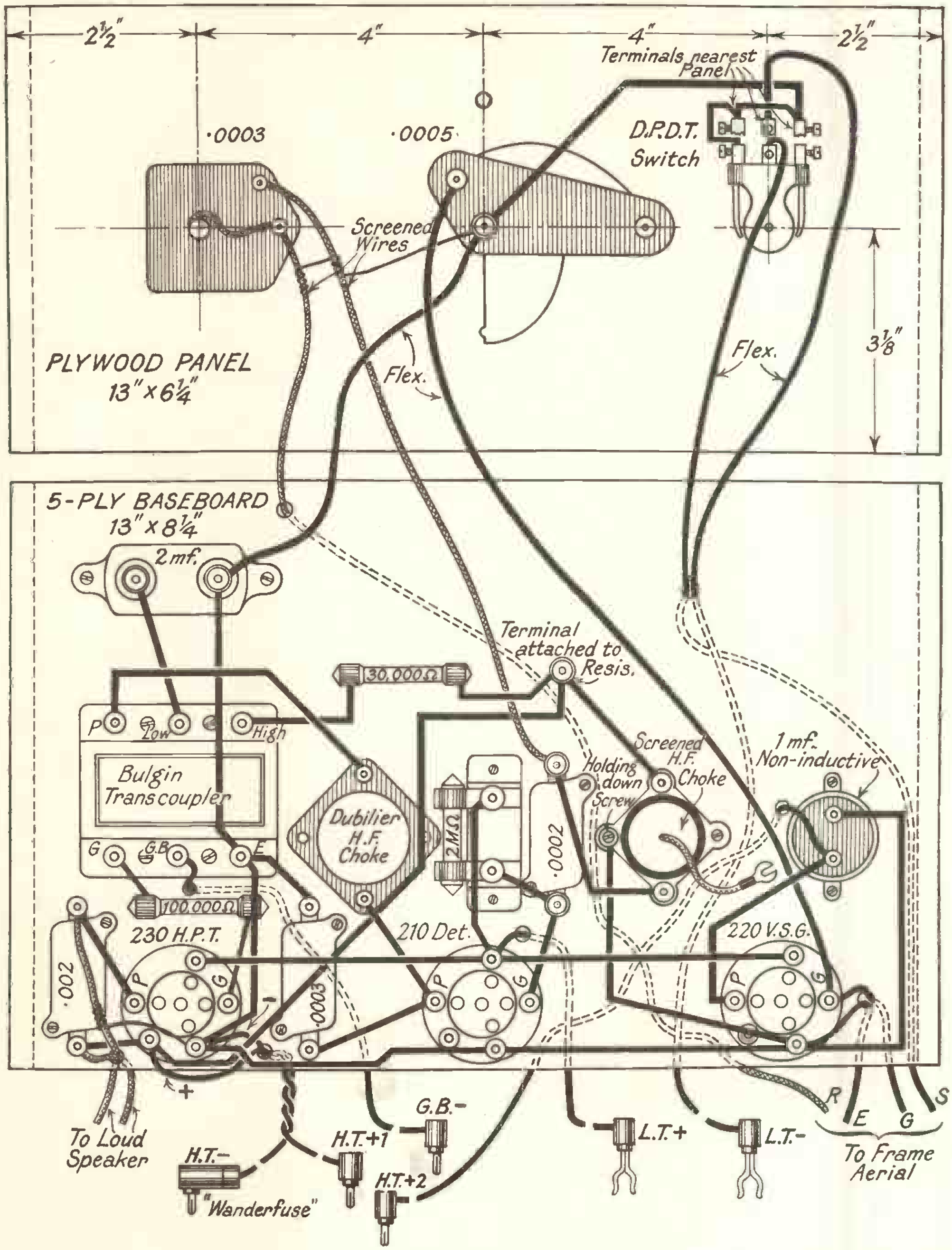


Fig. 3.—Wiring Plan for the "Simplicity" Three-Valve Portable.

on the choke-capacity principle, a screened high inductance choke being used for this purpose. This form of coupling removes the necessity for a second tuning condenser and thereby simplifies the task of tuning.

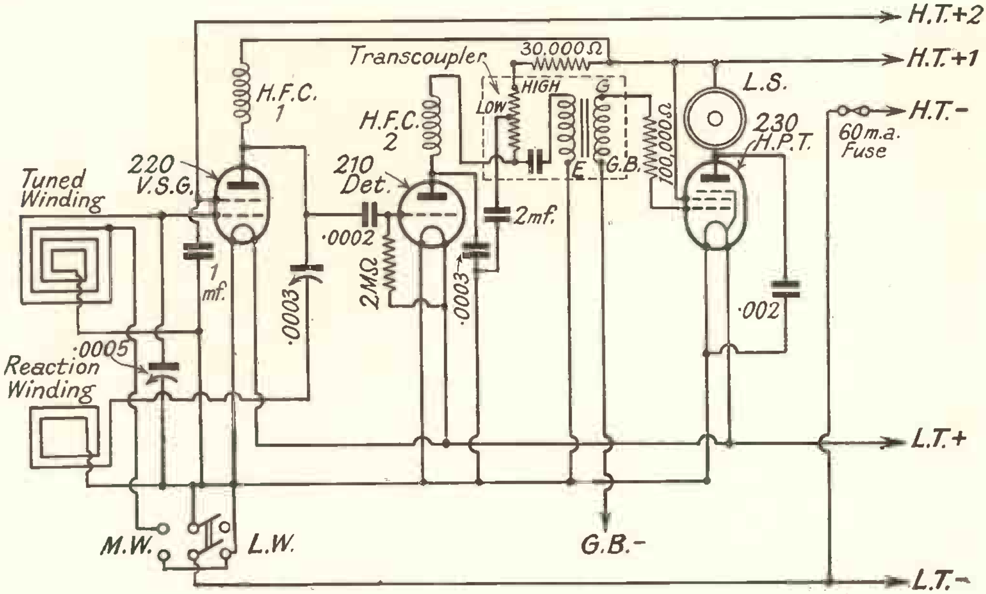


Fig. 4.—The Theoretical Circuit Diagram of the "Simplicity" Three.

THE COMPONENTS REQUIRED

1 ·0005 mfd. S.L.F. condenser (*Lotus*).
One Dial pointer (*Bulgin*).
1 ·0003 mfd. reaction condenser (*Lotus*).
1 2-way rotary switch, with window knob and "S.-off-L." dial (*Wearite type* 132).
3 5-pin valve holders (*Lotus*).
1 1 mfd. non-inductive condenser (*Dubilier*).
1 Screened H.F. choke with screened pigtail (*Wearite type* H.F.P.A.).
1 ·0002 mfd. fixed condenser (*Dubilier type* 670).
1 2-megohm grid leak (*Dubilier*).
1 Grid leak holder (*Dubilier*).
1 H.F. choke (*Dubilier type* 40).
1 ·0003 mfd. fixed condenser (*Dubilier type* 670).
1 resistance-fed L.F. transformer (*Bulgin* "Transcoupler").
1 30,000 ohm metallised resistance (*Dubilier*, 1 watt).
1 100,000 ohm metallised resistance (*Dubilier*, 1 watt).
1 2 mfd. fixed condenser (*Dubilier type* "BB").
3 Wander plugs; marked "H.T. + 1," "H.T. + 2," and "G.B. —" (*Belling Lee*).
1 "Wanderfuse," with 60 milliampere fuse (*Belling Lee*).
2 Spade terminals; marked "L.T. +" and "L.T. —" (*Belling Lee*).
1 Coil Glazite connecting wire (*Lewcos*).
1 Coil Metal braided connecting wire (*Lewcos*).
About 3 yards flex, ½-inch screws, etc.
1 25-yard reel 27/38 Litzendraht wire (*Lewcos*).
1 4-oz reel 26's gauge d.c.c. wire (*Lewcos*).
3 Terminal mounts (*Belling Lee*).
6 Terminals; plain black (*Belling Lee type* R).

(Approximate cost of above components is £2 10*s.* 0*d.*)

1 Suitcase portable cabinet, fitted with receiver chassis and aerial frame (*Longley Radio Mfg. Co.*).
1 Nickel plated station log (*Bulgin*).
3 valves; types 220 V.S.G. metallised; 210 Det. metallised, and 230 H.P.T. (*Cossor*).
1 Loud speaker unit (*Walters*).
1 L.S. cone collet (any make, available from all good wireless dealers).
1 99-volt H.T. battery with grid bias tappings (*Drydex type* "H. 1025, Yellow Triangle").
1 2 volt, 24 ampere-hours unspillable accumulator (*Exide type* "PC3").

Reaction

As mentioned before, reaction is applied to the frame aerial from the anode of the S.G. valve through the medium of a ·0003 mfd. variable condenser; this is the most satisfactory way of providing reaction when choke - capacity S.G. coupling is employed. Grid leak rectification is used and the normal values of grid leak and condenser are specified. An H.F. choke is inserted in the anode circuit of the detector valve to prevent the passage of H.F. currents into the L.F. amplifier and still further to prevent this, an easy H.F. leakage path is provided by the ·0003 mfd. fixed condenser joined between the detector anode and H.T. negative.

Fig. 5.—HERE THE BATTERY, FRAME AERIAL AND LOUD SPEAKER CONNECTIONS ARE CLEARLY SHOWN.

Resistance-fed Transformer

Coupling between the detector and pentode valves is provided by a Bulgin "Transcoupler," which gives rather more amplification than a transformer of the usual type, whilst at the same time being appreciably lighter in weight. The "Transcoupler" is fitted with a 50,000 ohm resistance, which is tapped at 30,000 ohms, and since the impedance of the detector valve specified is 13,000 ohms, only the 30,000 ohm portion is required for coupling purposes. In consequence, the remaining 20,000 ohm portion is used in conjunction with a separate 30,000 ohm resistance and a 2-mfd. condenser to provide de-coupling for the detector valve. If a higher impedance detector valve, such as a type "H." or "H.L." were to be used, better results would be obtained by using the whole 50,000 ohms for coupling, and therefore the 2-mfd. condenser should then be connected to the "Transcoupler" terminal marked "High" instead of that marked "Low."

The H.F. choke and by-pass condenser in the detector anode circuit should prevent the passage of any H.F. currents into the amplifier, but as an additional safety measure a 100,000 ohm resistance is included in the grid lead to the pentode valve.

Tone Compensation

The loud speaker is connected directly in the anode circuit of the pentode and no tone-regulating devices are used, or required. The reason for this might seem a little obscure because it is well-known that a pentode tends to give extra emphasis to high notes and so make reproduction rather shrill and piercing unless some kind of tone-compensation circuit is employed. In this case, however, the pentode itself *gives* "automatic" compensation because, due to the high degree of selectivity provided by the tuning circuit, a certain amount of high-note loss is inevitably introduced by it. The overall response is therefore good, and the quality of reproduction well up to standard of that provided by any up-to-date receiver.

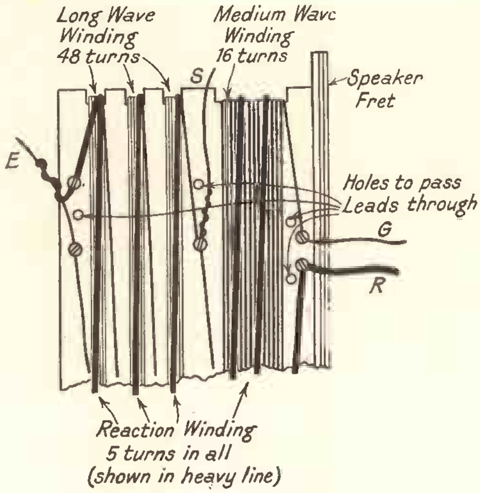


Fig. 6.—Details of the Frame Aerial.

Due to the loud speaker being in close proximity with the frame aerial it will tend to pick-up a small amount of high-frequency current from the aerial windings. To prevent any such current having a bad influence on the quality of reproduction, by causing instability, a ·002 mfd. by-pass condenser is connected between one speaker terminal and H.T.—to provide an easy leakage path for any H.F. current which is picked up.

Finally, it should be mentioned that a 60 milliampere fuse is included in the high-tension negative lead to prevent damage to the valves or H.T. battery in case of a wrong connection or a wire coming adrift and causing a short circuit.

Choice of Components

A list of components is given on p. 1034 and this should be accurately followed if good results are to be ensured. It is more than usually important that alternative parts should not be used, because in many cases they would not fit into the space provided. If, however, different components *must* be used for any reason, great care should be taken that they are of similar dimensions and identical characteristics to those specified.

By way of amplifying the above statement I would point out that if, say, Spaghetti resistances were used in place of the metallised ones there would be a danger of causing instability, and correct operation of the set might be impossible. A similar result would be produced by using an ordinary type of fixed condenser for the 1 mfd. component specified as being non-inductive. In the same way the use of an unscreened H.F. choke for coupling the S.G. and detector valves would almost certainly introduce complications.

Accessories

And now in regard to the accessories. The speaker fret is already drilled to receive the unit listed, so if a different one were to be employed this fact should be stated when ordering the cabinet, so that special provision could be made. The battery compartment measures 13 inches long by $5\frac{1}{4}$ inches wide by 5 inches deep, and this point must be considered when ordering the batteries. It will be noticed that a variable-mu screened-grid valve is specified, even though it is not used for volume control; this type of valve is somewhat more stable than an S.G. valve of the ordinary kind and so

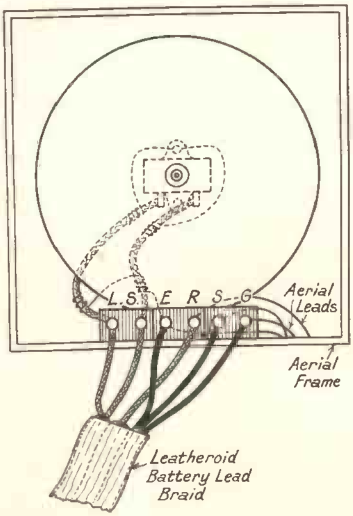


Fig. 7.—This shows the Connections from the Aerial and the Loud Speaker.

makes reaction control appreciably better and easier of manipulation. The detector valve given in the list has been found best for this circuit, but as explained above, a type "H." or "H.L." may be employed by making a slight modification to the wiring. On no account should a different type of pentode valve be used because it will most certainly consume far more high-tension current and cause the H.T. battery to have much too short a life.

Making the Set

The simple nature of the constructional work will be obvious from the wiring plan of Fig. 3 and the photographs.

Drilling the Panel

When the containing case is obtained the receiver chassis will be found to be attached by means of two screws passing through the sides. The first job is therefore to remove these and withdraw the chassis. Next remove the panel and drill it to receive the three components to be mounted on it; all holes are $\frac{7}{16}$ inch diameter and their positions are indicated in Fig. 3. Next mount all the components on the baseboard, duplicating the positions shown in the wiring plan.

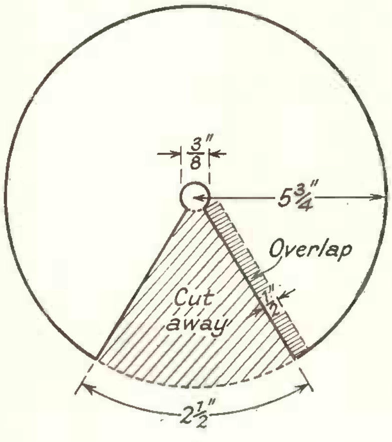


Fig. 8.—THE DEVELOPMENT OF THE LOUD SPEAKER CONE.

The Wiring

The wiring can now be begun by making as many connections as possible to the panel components. The wires to the switch must be made in short lengths of flex because the terminals are not large enough to take two pieces of the thicker connecting wire. Next proceed to wire up the baseboard components, using the Glazite insulated wire; some of the connections are made in flex and some in screened wire, but these should be left till last. Notice particularly that a wire is taken from one holding-down screw of the screened H.F. choke. This screw makes contact with a metal eyelet which is attached (internally) to the screening can, and the connection therefore "earths" the can to H.T. — .

Metallised Resistances

The two metallised resistances are wired up by means of their own connecting wires but a terminal is attached to one end of the 30,000 ohm component so that three leads can be attached to it.

Battery and Frame Aerial Connections

All battery, and three-frame aerial connections are in flex, as also are two of the wires between panel and baseboard components. Battery leads should extend about 12 inches from the set and the aerial leads, about 18 inches. All these wires are passed through holes made in the baseboard.

Screened Wires

Lastly, we come to the screened wires going to the loud speaker, frame aerial and reaction condenser. These are connected just like any others but care must be taken to see that the metal braiding is pushed back so that it cannot come in contact with the connecting wire running through it. In every case the screening braid must be joined to H.T. negative and these connections are most easily made by means of short lengths of 26's gauge wire bound tightly round the braid and joined to the most convenient H.T. — point; the actual connections are clearly shown in Fig. 3.

After the wiring is completed all the frame aerial and loud speaker leads should be threaded through the leatheroid braid supplied with the cabinet, and the battery leads fitted with wander plugs and spade terminals as shown in the wiring plan.

The Frame Aerial

And now we come to the job of winding the frame aerial, which will more easily be followed by studying the sketch of Fig. 6.

The Medium Wave Winding

First, we put on the medium wave winding, and this consists of sixteen turns of Litzendraht stranded wire wound in the longest slot on the aerial frame. The end of the wire is secured by tying it to a screw put in the frame and then the turns are placed side by side, allowing a small space between each ; the winding is finished by attaching the wire to a second screw.

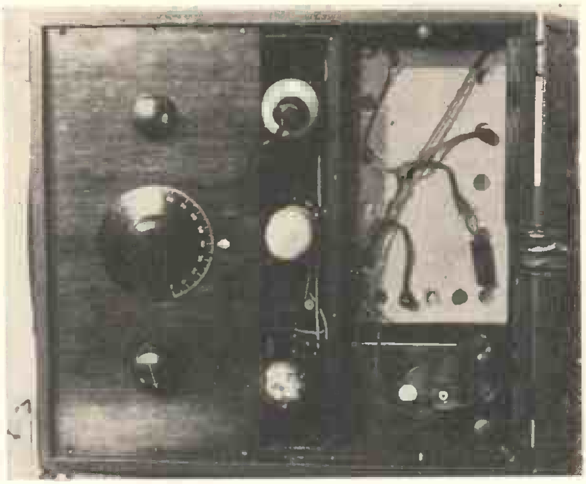


Fig. 9.—A Close-up Plan View of the Set. Showing the battery connections.

The Long Wave Winding

Next, the long wave winding, consisting of forty-eight turns of 26's gauge wire, is wound in the three smaller slots, putting sixteen turns in each. This winding must go in the same direction as the medium wave one and the ends of the wire can be attached to small screws as before.

The Reaction Winding

Lastly, we come to the reaction winding which is put on top of the other two. It consists of five turns in all of 26's gauge wire, of which two are put over the medium wave, and three over the long wave portions. The most important thing about the reaction winding is that it *must go in the opposite direction* to that of the tuned windings.

Joining the Ends of the Windings

When the windings are complete the "end" of the medium wave winding must be joined to the "beginning" of the long wave one and the ends of the reaction and long wave windings must be joined together. These joints might be made by baring the ends of the wires and twisting them together, but it is much better to solder them. Next, holes are made through the sides of the winding frame and the leads passed through to the inside.

The Loud Speaker

There is no difficulty in securing the loud speaker unit to the fret, and after this has been done, two 9-inch leads of screened wire should be attached to the terminals. The braid should be connected to one of the speaker mounting screws by means of a length of 26's gauge wire so that the metal body of the unit can be "earthed" through the braid.

If desired the leads from the set could be attached directly to those from the aerial and speaker but a much better job results if terminal connections are used as shown in Figs. 5 and 7.

Six terminals are used, and they are mounted on three Belling Lee terminal blocks ; actually the terminals are plain black but they are marked in Fig. 7 to correspond with the connections shown in Figs. 3 and 6. It will be seen that the braiding of the leads from the speaker is joined to the same terminal as the aerial lead marked "E."

The Speaker Cone

The speaker compartment is rather shallow, with a result that it will not take a standard size of cone. For this reason a cone must be made, as shown in Fig. 8 ; it consists of a sheet of stout cartridge paper cut to shape and glued. To make it a little more rigid a coat of shellac varnish is applied and the cone lightly baked in a warm oven. It is attached to the driving rod (which must be cut shorter with a pair of cutting pliers) by means of a small collet of the type sold by all good wireless dealers.

Connecting up and Using

It is best to give the set a trial with both chassis and aerial outside the containing case so that any necessary adjustments can easily be made. First connect up the speaker and aerial and then the accumulator. The H.T. battery supplies both high tension and grid bias, and should be connected as follows: (*a*) put the H.T. – plug into socket marked "H.T. – G.B. +"; (*b*) put the G.B. – plug into the 6-volt socket; (*c*) insert plug H.T. + 1 into the 90-volt socket and H.T. + 2 into the 54-volt one.

Switch on to long or medium waves by turning the switch knob to the right or left respectively, and then rotate the tuning dial until the local station is received. Its strength will be greatest when the axis of the frame aerial is in line with the transmitting aerial and so the frame should be rotated until maximum signal strength is obtained. Further adjustments to the volume can be made on the reaction condenser in the usual way.

When the set is being used some distance away from a transmitting station it might be necessary to adopt a rather different method of tuning. Thus, the reaction knob should be turned until the set is just oscillating (indicated by a faint breathing sound in the speaker) before "searching" by means of the tuning dial.

Stations will then first be heard as a whistle, and immediately such a sound is obtained the reaction should be reduced by turning the knob in an anti-clockwise direction. The transmission should then be heard quite clearly and can be brought up to full strength by carefully readjusting the tuning dial and rotating the frame aerial. It might be mentioned in passing that if the set is allowed to oscillate there is very little danger of its causing interference to other listeners using nearby receivers.

If the Fuse "Blows"

If the set suddenly stops working or if no sounds are heard, unscrew the "Wanderfuse" and see if the fuse has "blown"; if it has, carefully examine the set for a wrong connection and make sure that none of the shielded wires are touching other components. After tracing the fault the fuse may be replaced, when the set should work properly. *Do not replace the fuse before finding the cause of the short-circuit.*

When everything is found to be in order the set can be placed in the containing case and all the battery and aerial leads passed below the partition. Connect up to the aerial terminals and screw the frame into the lid. The batteries can then be put into their compartment and connected up as before; prior to putting the cover over them it would be as well to try the effect of altering slightly the positions of plugs "H.T. + 2" and "G.B. –" until the most suitable voltages are found.

A "station log" is specified and is attached to the battery partition cover by two screws. It will be found useful for making a note of the dial readings for various stations.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XVI—AMPLIFICATION OF WIRELESS SIGNALS

FROM our studies of the behaviour of a wireless valve we have discovered that the valve acts as an amplifier of voltages. A small variation of voltages applied to the grid of the valve will result in the variation of large voltages across the anode, provided that the latter is connected to some device such as a high resistance, and inductance or a transformer.

Resistance in Series with Valve Anode

Let us consider in the first place the behaviour of a circuit which has a resistance in series with the valve anode. Such a circuit is shown in Fig. 1a. Here, as you see, we have the aerial tuning circuit to which is connected a high-frequency amplifying valve. The anode of this valve is connected to the H.T. battery through a resistance of the order of some tens of thousands of ohms. (The value of this resistance depends upon the impedance of the valve.) The first valve is coupled to the second valve, which is also an H.F. amplifying valve, through a condenser and grid leak, while in the anode of the second valve there is another resistance. The last valve is a detector valve to which telephones are connected.

Purely Theoretical Considerations

Apart from a few refinements, which are omitted in order to make the diagram as simple as possible, the circuit shown is a working circuit and can be constructed with good results, provided the values of various components are suitably fixed. You will find a wealth of information on this subject in the numerous practical constructional articles in this work, so that there is no need for us to go into full details, and we can confine our attention, for the moment, to purely theoretical considerations of the various methods of amplification.

The Problem

Our problem is to get hold of comparatively weak oscillating voltages across the tuner, voltages induced by the passing electro-magnetic waves, and with the help of a number of valves and suitable components magnify these voltages in such a way that the final voltage applied across our reproducer, be it telephones or a loud speaker, is so considerable that the reproducer in question will give an ample volume of sound.

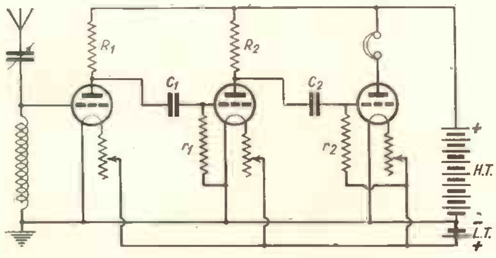


Fig. 1A.—A CIRCUIT HAVING RESISTANCE IN SERIES WITH THE VALVE ANODE.

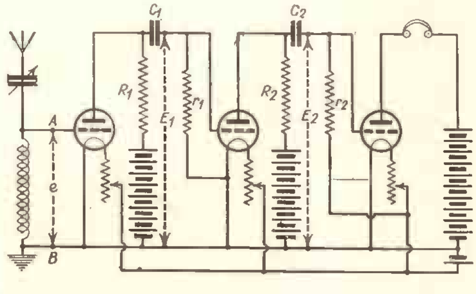


Fig. 1B.—THE SAME CIRCUIT AS FIG. 1A REDRAWN WITH SEPARATE BATTERIES FOR EACH VALVE.

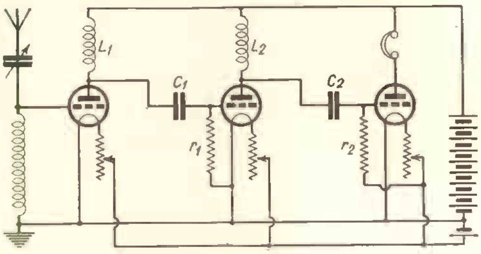


Fig. 2A.—Coupling by High-frequency Choke.

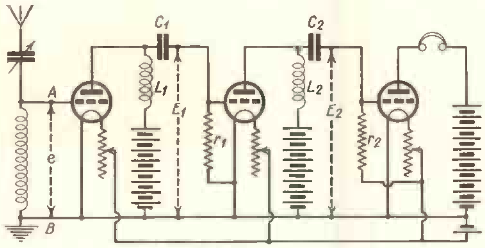


Fig. 2B.—Coupling by High-frequency Choke.

Two General Methods of Amplification

There are two general methods of amplification. We can amplify the received voltages before they are impressed across the grid circuit of the detector valve, or we can start with a detector valve connected to the tuner and amplify the output of the detector valve. The first method is the better of the two as a detector valve works more efficiently with a large input.

High-Frequency and Low-Frequency Amplification

When the amplification is carried out before the detector stage it is said to be *high-frequency amplification*, as in this case we are amplifying our voltages before they are rectified. Amplification after the detector stage is referred to as *low-frequency amplification*.

In practice both methods are used simultaneously, *i.e.*, aerial applied voltages are amplified both before and after the detector stage.

In order to be able to grasp clearly the series of events taking place in a wireless receiver, let us examine the various methods of amplification in turn, so that our diagrams are comparatively simple and are easily understood by the reader.

Separate H.T. Battery for every Valve

The circuit shown in Fig. 1a is drawn in a conventional manner, which is used by everybody. But this method of representing a circuit obscures considerably the happenings in its various parts and for this reason—the circuit in question is redrawn as shown in Fig. 1b. In comparing the two diagrams you will notice that, while the position of the various components is the same, a separate H.T. battery is introduced for every valve. This is quite a legitimate proceeding, although somewhat expensive, and will work as well as in the case of a H.T. battery, common to all valves. The two circuits are thus identical in performance and arrangement of components. Now let us see what the resistance in the anode circuit does to help us to amplify voltages from valve to valve.

Varying Voltage Across Grid Circuit

When our receiver is in operation there is a varying voltage, let us call it *e*, developed across the grid circuit of the first valve, *i.e.*, across the points A and B. As you already know, small variations in potential across the grid will result in large variations in the value of the current flow-

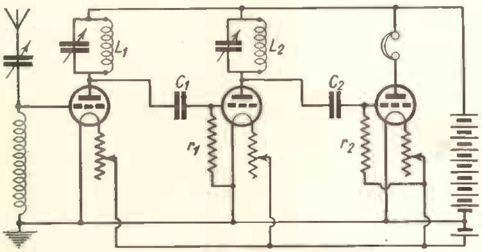


Fig. 3A.—Tuned Anode method of Coupling.

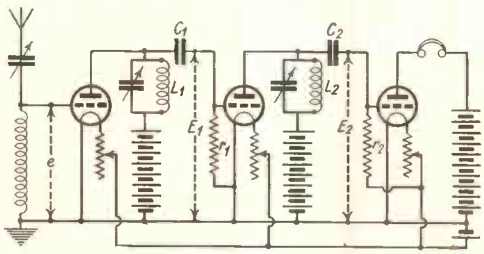


Fig. 3B.—Tuned Anode method of Coupling.

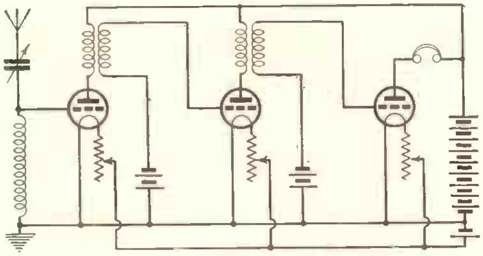


Fig. 4A.—THE TRANSFORMER METHOD.

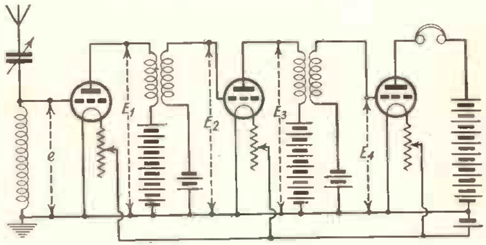


Fig. 4B.—THE TRANSFORMER METHOD.

ing in the anode circuit. (If you are not clear on this point please read once more my articles on valves.)

Voltage Developed Across a Resistance

Now, in considering the first valve we see that the anode circuit consists of the anode of the first valve, the resistance R_1 and the separate H.T. battery. From Ohm's law we know that the voltage developed across a resistance is equal to the product of the resistance value and the current flowing through it (E = RI).

Anode Current Varies with Grid Voltage Variation

Since the voltage on the grid varies all the time with the variations of the received wave, the anode current will also vary and therefore the voltage developed, at every instant, across the resistance R_1 will also vary. The variations across the resistance will be of the same nature as the variations across the grid of the valve, as the anode current follows faithfully every variation on the grid, and for this reason we shall find that the voltages developed across the resistance are considerably larger than the voltages applied in the first place to the grid of the first valve.

First Step in Amplification

Let us call the voltage developed at every instant across the resistance, E_1. It is clear that E_1 is of the same nature as *e*, only much larger. This is our first step in amplification. From diagram shown in Fig. 1b you will see clearly that the voltage E_1, which is developed across the resistance R_1, is automatically applied across the grid of the second valve. Thus, the second valve is able to start with a much larger voltage than the first valve. But once more the voltage applied across the grid of the second valve results in variations of much larger voltages across the resistance R_2 so that the voltage E_2 developed across the resistance R_2, and therefore across the grid of the third valve is very much larger than the starting voltage *e* across the points A and B.

The last valve magnifies further the E_2, so that we get across the telephones the final voltage which is capable of driving a considerable current through the telephone windings, a current which produces a strong varying magnetic field and thus the telephone diaphragm is able to vibrate with considerable energy, producing a large volume of sound.

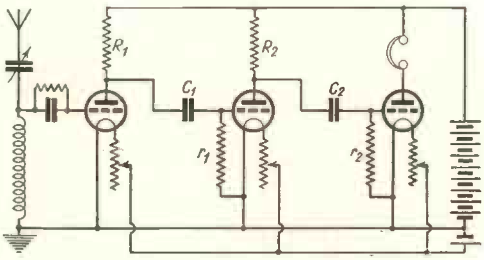


Fig. 5A.—RESISTANCE-CAPACITY COUPLING ON L.F. SIDE.

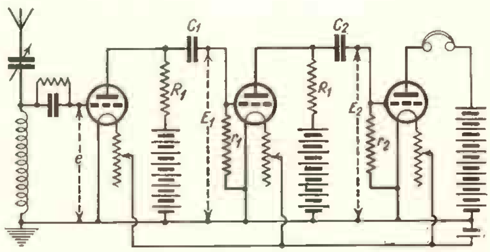


Fig. 5B.—RESISTANCE-CAPACITY COUPLING ON L.F. SIDE.

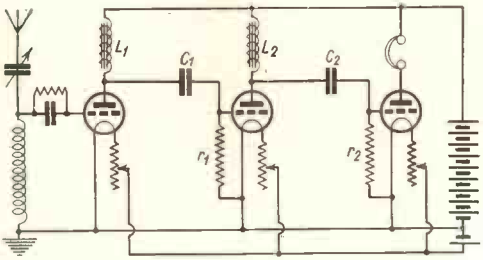


Fig. 6A.—Low-frequency Chokes for Inter-valve Coupling.

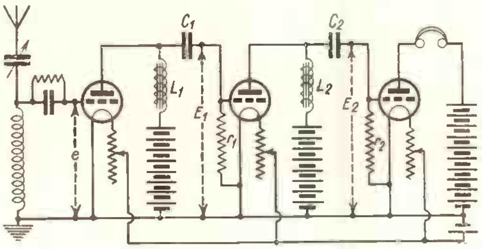


Fig. 6B.—Low-frequency Chokes for Inter-valve Coupling.

Resistance-Capacity Coupling

This method of amplification is called *resistance-capacity coupling*, the name being derived from the use of a resistance in the anode circuit and the coupling condenser with its grid leak between the anode of the valve and the grid of the following valve.

Resistance-capacity coupling, which is here shown in the high-frequency circuit, is not recommended to be used as such. While it gives excellent results on the low-frequency side, it is not so satisfactory on the high-frequency side. But care should be taken not to use resistance-capacity coupling on either side with wavelengths above 1,000 metres, as the amplification is very noisy. A good deal depends on the values of the anode resistance and the value of the coupling condensers and grid leaks. All these have to be taken into consideration by the designer.

The advantage of resistance-capacity coupling on the low-frequency side is that no iron is introduced in the anode circuit and therefore there is no danger of distortion taking place.

High-frequency Choke

Now let us see what will happen if we replace our anode resistance by a suitable inductance. On the high-frequency side we use for this purpose a coil called a *high-frequency choke.* This is a coil wound on a wooden or ebonite former, so that there is only air inside the coil and no iron present. Sometimes such a coil is spoken of as an *air-core choke.*

From Fig. 2b we see once more that the initial voltage across the points A and B is developed into a magnified voltage E_1 across the coil L_1 and the H.T. battery. When a varying current is flowing through the anode circuit, and therefore through the coil in series with the anode of the valve, the self-inductance of the coil comes into play. This is due to the magnetic field coming into existence around the coil and, while it is varying with the varying current both in extent and direction, now growing outwards, now collapsing upon itself, *i.e.*, upon the coil, its lines of force cut the individual turns of the coil and induce in them E.M.F.'s which are always in opposition to the main E.M.F. applied across the coil. It will become clear if you think of these induced E.M.F.'s as producing currents in opposite direction to the anode current.

When the anode current tries to grow, the coil, under the influence of the magnetic field, sends currents in the opposite direction and thus reduces (chokes the current).

When the anode current tries to decrease and the magnetic field is collapsing, owing to the movement of the magnetic lines of force in the opposite direction to the previous one, the E.M.F.'s are reversed and the opposing currents reverse their direction, flow in the same direction as the diminishing anode current, and thus swell the number of electrons and, for the time being, increase this current.

Back E.M.F.

Thus, at every instant there is the so-called *back E.M.F.* across the coil. This back E.M.F., varying with the variation in intensity of the anode current, will act across the coil connected in the anode circuit in a similar way in which the resistance was acting previously.

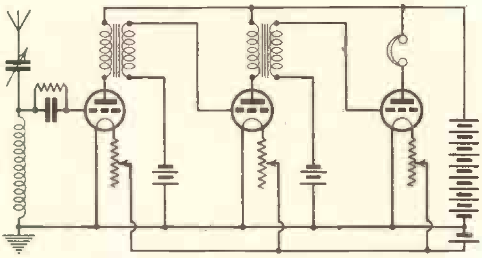


Fig. 7A.—Low-frequency Transformer Coupling.

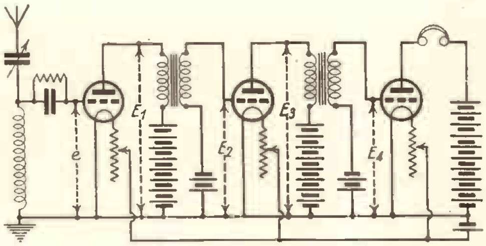


Fig. 7B.—Low-frequency Transformer Coupling.

Alternating E.M.F.

In the case of resistance we had a varying *direct* E.M.F. developed across the resistance, and the variations of this E.M.F. were in step with the variations of the anode current. In the case of the inductance, *i.e.*, a high-frequency choke, or a low-frequency choke for that matter, *the E.M.F. developed across the inductance is an alternating one.*

The reason for this is that the lines of force of the magnetic field around the coil cut the conductors in one direction when spreading and in the opposite direction when contracting, and therefore the E.M.F. is reversed once every cycle. The alternating E.M.F. E_1 is applied across the grid of the second valve. The E.M.F. developed across the coil L_2 is also an alternating one and is applied to the grid of the third valve.

The Tuned Anode

Very often it is found necessary to tune the high-frequency coil in the case of *inductance-capacity coupling*, *i.e.*, in the case of a high-frequency choke included in the anode circuit, and this leads us to the *tuned anode*. This method of coupling is shown in Figs. 3a and 3b.

In this case, as in the case of any tuned circuit, the coil is tuned to give best results on some predetermined band of wavelengths. The action from the amplification point of view is the same as in the case of an untuned coil.

The Transformer Method

The third method of amplification is the transformer method. We shall discuss in detail the principles of the working of the transformer when we are dealing with low-frequency amplification, and in the meantime let us be satisfied with the fact that (Fig. 4b), the applied E.M.F. *e* results in a varying anode current which is flowing through the primary winding of the transformer. This current produces a magnetic field around the primary coil, and as this magnetic field varies in intensity it induces an E.M.F. in the secondary winding. The E.M.F. developed across the secondary is applied, as can be seen from Fig. 4b, across the grid of the next valve. The E.M.F. E_1 is larger than the applied E.M.F. *e*.

The high-frequency transformer which consists of two windings, the primary and the secondary, mounted on a wooden or ebonite former (air core) works more on the principle of two inductances mounted side by side and in some measure the two windings act as a form of condenser owing to the self-capacity of the two windings, than a true transformer such as an iron core transformer. The magnitudes of E_1 and E_2 differ little from each other, especially that, as a rule, the primary and the secondary of an air-core transformer have the same number of turns. We can say, therefore, that the high-frequency transformer is a sort of inductance capacity coupling similar in behaviour to the H.F. choke.

Resistance-Capacity Coupling on L.F. Side

Resistance-capacity coupling used on the low-frequency side is quite an efficient method of amplification giving good results. The quality of reproduction is usually better than that with L.F. transformers, as there is no iron to introduce distortion. The action of the L.F. circuit is identical with that of the H.F. similar circuit explained above, as can be seen from Figs. 5a and 5b.

Low-frequency Chokes

Now let us turn to Figs. 6a and 6b, which illustrate low-frequency chokes used for inter-valve coupling after the detector valve. While the high-frequency choke is wound on an "air core" and has no iron inside it, it can deal with high-frequency currents without unduly impeding them and thus give the desired high-frequency variations of back E.M.F. In the case of the low-frequency choke which is wound on an iron core which consists, as a rule, of a bunch of thin iron wire, each strand being insulated from the other in order to avoid eddy currents. Only low-frequency currents are able to get through, and the high-frequency current can only pass the choke on account of the self-capacity of its turns.

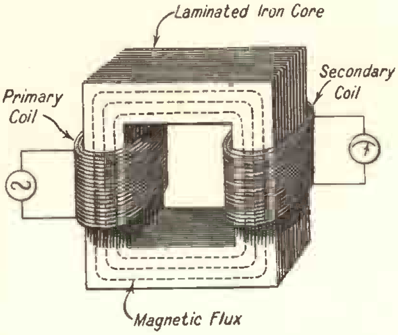


Fig. 8.—Details of a Transformer.

Why a By-pass Condenser is Used

Usually a by-pass condenser for high-frequency currents is connected across the L.F. choke. The reason for such behaviour is that the iron in the core which carries the bulk of the lines of the magnetic field developed by currents passing through the choke, is unable to magnetise and demagnetise with the rapidity of the high-frequency currents, and the latter are therefore impeded in their flow to such an extent that they have to seek an alternative path and utilise the capacity between the turns of the choke or go *viâ* a by-pass condenser. In the case of the low-frequency currents the core is able to follow the slow variations and can magnetise and demagnetise in time. For this reason very little opposition is being offered by the choke to the passage of low-frequency currents.

From Fig. 6b it is obvious that amplification is being carried out in the same way as in the case of the H.F. circuit. The back E.M.F. E_1 due to the choke is much larger than e, is of an alternating nature and is applied directly across the grid circuit of the second valve.

In Figs. 7a and 7b we are dealing with L.F. transformer coupling.

How the Transformer Amplifies Signals

Let us consider an arrangement such as shown in Fig. 8 (and see what such a transformer does to amplify signals). Here we have a laminated iron core representing a closed path as far as the lines of force of the magnetic field are concerned. Two coils are mounted on this core. Now, if we apply a source of an alternating E.M.F. to, say, the left-hand coil, as the E.M.F. varies in intensity and direction, an alternating current will flow through the coil, since the circuit is closed, and alternating magnetic field will come into existence around the coil. Since iron is provided within the coil and since iron passes magnetic lines of force more readily than air, the bulk of the lines of force of the magnetic field will be concentrated within the core. Thus a strong magnetic field will be introduced within the secondary coil as well (see how the lines of force arrange themselves within the core).

This alternating magnetic field within the right-hand coil will cut the conductors of this coil and will induce in it an E.M.F., and since the right-hand coil represents a closed circuit with the indicating instrument being connected

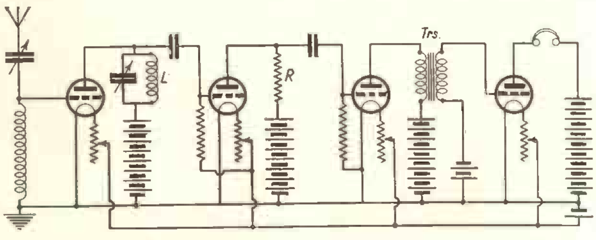


Fig. 9.—Circuit in which both H.F. and L.F. Amplification is used Simultaneously.

across it, an alternating current will flow in the right-hand coil.

Input of Power Equals Power Output

If we measure the current and the voltage across the left-hand coil and do the same with the right-hand coil we shall discover that approximately the product of current and E.M.F. in each coil is the same. I said approximately, because there is a slight loss of energy in the transfer from one coil to another, but as the transformer efficiency is of the order of 97 per cent., we can neglect these losses and for the time being say that the input of power (power = EI) to the left-hand coil (primary coil) is equal to the power output of the right-hand coil (secondary coil).

Suppose we have a current of 2 amperes flowing with an E.M.F. of 100 volts applied to the primary. Then the power input to the primary is 200 watts. According to the above, and always neglecting the slight losses, the secondary output is also 200 watts.

Different Combinations of Current and Voltage

But there are different ways in which we can make up 200 watts. Look at this :—

1 ampere × 200 volts = 200 watts.
2 amperes × 100 volts = 200 watts.
10 amperes × 20 volts = 200 watts.
½ ampere × 400 volts = 200 watts.

Thus, it is clear that for the same power output and input we can have different combinations of current and voltage. How do we vary the current with a given voltage ? Why, by varying the resistance of the circuit. And how can we vary the resistance of a coil ? By varying the number of turns in it. The more turns we have the higher the resistance and the smaller will be the current through the coil with the same voltage.

A Typical Case

This being the case, suppose we have 100 turns in the primary. Suppose this will give us a current of 1 ampere at 200 volts. Thus, with a 100 turns on the primary, the primary input is 200 × 1 or 200 watts. This means that the secondary will give us an output of 200 watts.

Now, suppose that the secondary has double the resistance of the primary. In other words, the secondary has 200 turns instead of 100. If the resistance is double the current should be halved. Therefore in the secondary, instead of having 1 ampere flowing we have ½ an ampere flowing. (This reasoning, although strictly correct with a direct current, from the resistance point of view, is not quite correct in the case of an alternating current, but it is near enough for the purpose of our argument.)

Since the output of the secondary is 200 watts with ½ of an ampere, the voltage developed across the secondary coil must be 400 volts (see the table above). You see what happened ? By doubling the number of turns in the secondary coil we have doubled the voltage across it. Since

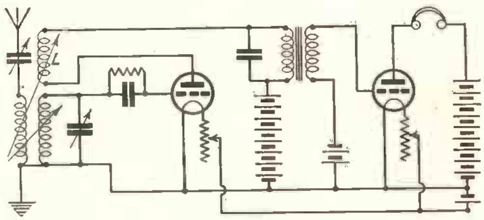


Fig. 10.—REGENERATIVE AMPLIFICATION.
This method of amplification is more commonly known as reaction.

the input of the primary coil is equal to the output of the secondary coil, we have in the primary a smaller voltage and a larger current, and in the secondary we have a smaller current and a larger voltage.

Step-up Transformer

This means that by using a transformer we can get a larger voltage across the secondary than that across the primary provided that the secondary coil has a larger number of turns than the primary. In this manner we are stepping up the voltage, and for this reason a transformer which has more turns on the secondary than on the primary is called a *step-up transformer*. If we divide the number of turns on the primary by the number of turns on the secondary we shall get the *transformation ratio*. This is why we talk about transformers having a ratio of 1 : 3 or 1 : 5. This simply means that the

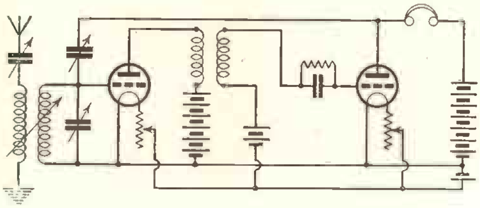


Fig. 11.—CAPACITY REACTION.

secondary winding has three or five times the number of turns of the primary winding.

Now to return to our transformer.

Primary.	*Secondary.*
Number of turns: 100.	Number of turns: 200.
Applied voltage: 200 volts.	Output voltage: 400 volts.
Current: 1 ampere.	Current: $\frac{1}{2}$ ampere.
Input power: $200 \times 1 = 200$ watts.	Output power: $400 \times \frac{1}{2} = 200$ watts.

We know that the input power and the output power are equal.

Volts per Turn in Primary and Secondary are the same

In the primary we have 100 turns with 200 volts applied to them, which means that there are 2 volts for each turn. In the secondary 200 turns are developing 400 volts. We can consider the magnetic field inducing a certain voltage across each turn, and these " turn-voltages " being in series will add up, as in the case of a number of cells in series. Therefore the secondary will develop 2 volts per turn. This brings us to the second law in connection with transformers, and that is that *the volts per turn in the primary and the secondary are the same.* This gives a method of fixing our voltages and turns without bothering about the current. If we have a primary with 200 turns and an applied voltage of 400 volts, we know that the volts per turn on the primary, and therefore on the secondary is 2. If we want a secondary voltage of 1,000 volts, and since we can get only 2 volts per turn, the secondary must have 500 turns.

Step-down Transformer

If the secondary of a transformer has fewer turns than the primary it means that it will be stepping down the applied to the primary voltage and for this reason such transformers are called *step-down transformers.* The so-called telephone transformers are of this kind.

In a step-down transformer we start with a large voltage and small current in the primary and finish with a smaller voltage and a larger current in the secondary, so that we may say that a step-up transformer amplifies voltages, while a step-down transformer amplifies currents.

Coupling Valves with L.F. Transformers

This being the case let us now turn to Figs. 7a and 7b, in which the method of coupling valves with the help of L.F. transformers is shown. The transformers in this case are step-up transformers (the secondary winding has many more turns than the primary winding and is therefore developing a higher voltage than that applied to the primary).

In Fig. 7b we see that the anode current in the first valve is flowing through the primary winding of an L.F. transformer. The voltage developed across the primary is larger than the voltage applied across the grid of the first valve. The voltage developed across the secondary is still larger and this is applied directly across the grid of the second valve. The same process of amplification is repeated with the second transformer.

As I have already said, both H.F. and L.F. amplification can be used simultaneously. This is shown in Fig. 9.

Regenerative Amplification

There is another method of amplification, called *regenerative amplification* or commonly known as *reaction.* This is shown in Fig. 10. You will notice that the aerial tuning circuit is loosely coupled and that there is a coil connected in the anode circuit of the first valve, which is the detector valve. This coil is shown in series with the primary of a L.F. transformer.

What happens in this case is that the E.M.F. developed across the primary tuning (aerial) coil is inductively passed to the secondary aerial coil, *i.e.*, across the grid of the first valve. This results in an amplified E.M.F. across the primary of the transformer and therefore across the anode coil L, which is the reaction coil. This reaction coil acts by induction on the primary aerial coil to which it is coupled and induces in it the magnified E.M.F., which has been developed across the anode circuit of the first valve.

This magnified E.M.F. is added (if the reaction coil is connected the right way round) to the incoming E.M.F., so that the final E.M.F. applied at every instant across the grid of the first valve is much larger than it would have been without the reaction coil. This means that we first amplify the received E.M.F. and add to it by induction the amplified voltages.

Capacity Reaction

The same result can be achieved with *capacity reaction*, which is shown in Fig. 11. Here, energy is being transferred back to the tuner with the help of a condenser in the anode circuit of the first valve.

Please note that it is not usual in practice to use a separate H.T. battery for each valve and that this method of showing circuits has been introduced simply for the purpose of indicating clearly how voltages are passed from one component to another. In the next section I shall deal with the reproducing systems, such as telephones and the various types of loud speakers, and in the following part I hope to take an average receiving circuit and show what happens in it starting from the aerial and earth terminals and finishing with the loud speaker.

QUESTIONS AND ANSWERS

Why is High-Frequency Amplification Desirable ?

Because a detector valve works more efficiently with a large input.

What are the Three Methods of Coupling Valves ?

(1) Resistance-capacity coupling.
(2) Inductance-capacity coupling.
(3) Transformer coupling.

State the Advantages and Disadvantages of Resistance-capacity Coupling

The advantage of resistance-capacity coupling on the low-frequency side is that no iron is introduced in the anode circuit and therefore there is no danger of distortion taking place.

Resistance-capacity coupling, although it gives excellent results on the low-frequency side, is not so satisfactory on the high-frequency side. Care should be taken not to use resistance-capacity coupling on either side with wavelengths above 1,000 metres, as the amplification is very noisy.

What is the Difference between H.F. and L.F. Chokes ?

H.F. chokes have an air core.
L.F. chokes have an iron core.

What is the Difference in Action between H.F. and L.F. Chokes ?

H.F. chokes can deal with high-frequency currents without unduly impeding them and thus give the desired high-frequency variations of back E.M.F. In the case of L.F. chokes only low-frequency currents are able to get through.

State Briefly the Difference between Step-up and Step-down Transformers

A step-up transformer amplifies voltages ; a step-down transformer amplifies currents.

DUAL BALANCED LOUD SPEAKERS AND AMPLIFIERS

By EDWARD W. HOBBS, A.I.N.A.

EXPRESSIONS such as a "balanced pair of loud speakers," mean that two separate compensated loud speakers are mounted close together on a single baffle board or in a suitable baffle box, and played simultaneously.

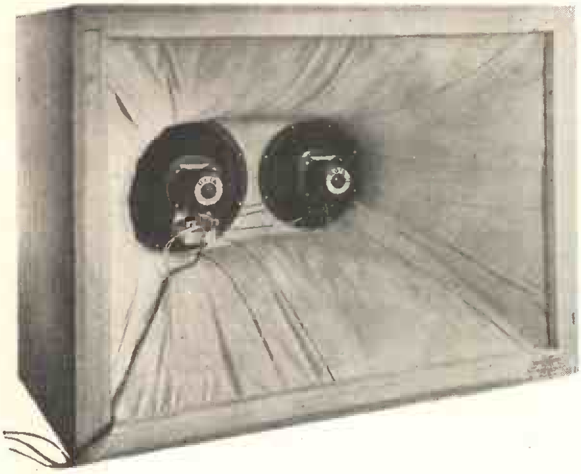


Fig. 1.—A PAIR OF BALANCED SPEAKERS IN A BOX BAFFLE.

This combination of energised balanced dual speakers in the "Howe" B.B.C. box baffle is capable of almost perfect musical reproduction.

Such a combination is potentially capable of practically perfect reproduction of radio or gramophone music, provided the best use is made of the speakers, and particularly the manner in which they are housed.

Why Dual Speakers Excel

Dual balanced speakers are preferable to a single speaker because of the increased efficiency of the bass and middle registers, the peaks and valleys in the upper registers are levelled up and there is an improved power handling capacity largely due to the mutual shunting of the speech coils when connected in parallel.

Moreover, on the score of expense, a small pair of dual speakers cost little or no more than a single speaker of equivalent power handling capacity.

Comparative Sound Dissipation

Another point to bear in mind is that two separate 6-inch diameter speakers have a combined sound-dissipating area equal to that of a single 8½-inch diameter speaker, but for a given sound output, the load on the dual speakers is roughly half that of the larger single speaker.

Finally, there are peculiarly pleasing qualities with dual speakers due to the facts that sounds emanate from two different places and they have a brilliance or "attack" that adds greatly to the realism of the reproduction.

This quality of brilliance is probably due largely to the ability of relatively small speakers to accelerate more rapidly than a large speaker, when played under similar conditions.

Large size balanced pairs of speakers are of course available, as well as combinations of small and large diameters.

How Dual Speakers are Balanced

Pairs of speakers can be compensated in various ways; for instance, the Celestion Dual Speaker, where each speaker has certain duties allotted to it, one takes care of the high notes, the other looks after the bass, and between them they cover efficiently a wider frequency range than a single speaker. Some such arrangements

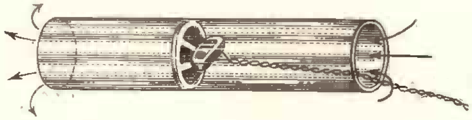


Fig. 2.—LOUD SPEAKER IN TUBE.

The loud speaker shown fitted in a long tube acts as a piston and drives the air forwards. Pure tone depends largely on the length of the air path.

may need the use of separate cut-off filters to prevent overlap or mutual modulation and the introduction of distortion.

Another system utilises two straightforward speakers with slightly different frequency ranges, and are so designed and made that the inherent frequencies and resonant points are compensated or balanced out.

This compensating or balanced system works extremely well in practice if the speakers are well produced, for example, the "Celestion Reetone" matched pair, with equal size diaphragms having dissimilar characteristics to eliminate boominess and augment the bass output.

It should be appreciated that merely playing two speakers simultaneously will not give the same result ; it is essential that the deficiencies of each speaker are balanced out by the other.

Size of Speakers to Use

Balanced compensated pairs of "Rola" loud speakers can be had in various sizes, with fields excited by permanent magnets or with current energised fields.

One instance of the proper application of a pair of 6-inch cone permanent magnet "Rola" speakers is given in the "Clock Case Receiver," described in detail elsewhere in COMPLETE WIRELESS. These are the smallest compensated pair at present made, but give excellent results with any good 3-valve set. They were tested with the "Dual Purpose Three," described on pp. 652 to 663 of COMPLETE WIRELESS, and gave quite satisfactory results ; when used with a powerful A.C. mains 3-valve set the volume of pure undistorted sound is too great for the average room, consequently, this small balanced pair may be taken as adequate for ordinary domestic use with battery operated or small mains sets.

Field Excited Pairs

When the highest possible quality of reproduction is required—or sufficient volume for very large rooms—it is desirable to use balanced pairs with field resistances ; for domestic use a pair of F5 "Rola" speakers with 6-inch cones will fill most requirements, but for larger outputs a pair of F6 with $7\frac{3}{4}$-inch cones should be selected. For concert use or for reception of radio at its best with majestic volume and well-nigh perfect interpretation of every note, overtone and transient, the combination shown in Fig. 1 would be satisfactory. It comprises a "Howe" dual speaker box baffle with a F6, $7\frac{3}{4}$-inch cone, and a F7, 9-inch cone, balanced compensated "Rola" speakers.

Incidentally, the same arrangement is equally effective in conjunction with a pick-up and amplifier for the electrical reproduction of gramophone records.

Matching Speakers to Valves

The importance of correctly matching the loud speakers and output valves is not dealt with here, but is dealt with fully on pp. 707 to 719 of COMPLETE WIRELESS.

Importance of the Baffle

No matter how good the speakers may be in themselves, there are two items that have to be considered before the anticipated results are obtained. First of all

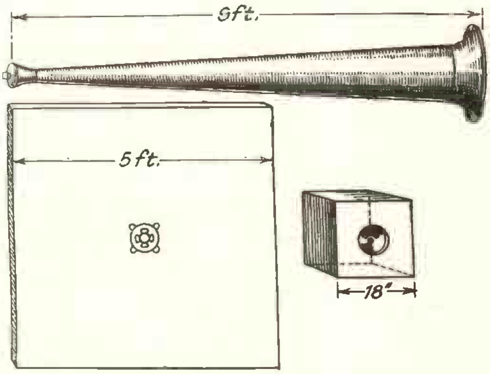


Fig. 3.—COMPARATIVE SIZES OF BAFFLES.

To ensure uniform and correct final response, a trumpet would be 9 feet long, a flat baffle 5 feet square, and a box baffle 18 inches square by 10 inches deep. The diagram shows their relative sizes.

the receiver must be capable of delivering sufficient pure and undistorted power from the last valve to drive the speakers; a dual pair cannot convert a bad receiver into a good one.

The second item, and it is really of the utmost importance, is the provision of an adequate baffle, as without it the bass response will be lost and much of the brilliance and purity of the higher notes will be missing.

Pure Sounds

It may be helpful to some readers to digress for a moment and explain briefly why a large baffle is essential for realistic reproduction of sounds.

Imagine an ordinary moving coil speaker fixed in a glass tube, as shown in Fig. 2, and that a pulse of electric current passes through the speech coil. This causes the cone to move forward like a piston, a small but definite amount, and in so doing several things happen simultaneously.

Fig. 4.—THE "HOWE" BOX BAFFLE.

The box is lined with absorbent slag wool which eliminates all resonance and ensures remarkable realism of reproduction.

First, the air in front of the cone is pushed forwards out of the front end of the tube, and at the same time air flows into the back of the tube to fill up the space behind the cone; there is thus a flow of air, or, more strictly, a flow of energy from the front to the back of the cone.

Length of Air Path

Without going deeply into technicalities, it suffices to point out that for the correct reproduction of sounds the minimum length of the air path from front to back of the speaker cone is determined by the pitch or frequency of the various musical notes; thus a normal speaking voice with a frequency of about 200 c.p.s. requires a length of about 18 inches; a high-pitched note about 1,000 c.p.s. needs a length of only about $3\frac{1}{2}$ inches.

Bass Response

The low tones and bass notes, those around 50 c.p.s. require a length of about 9 feet if full justice is to be done to them.

Loud speakers of good quality—or well-balanced pairs—are capable of responding to the whole harmonic range, but unless the air path length is controlled, the beauty of the notes cannot be realised.

It is quite impracticable to get realistic

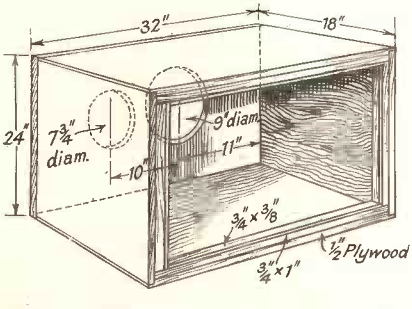


Fig. 5.—DIMENSIONS OF BOX BAFFLE.

The sizes here given are suitable for use with any dual pair of speakers of $7\frac{3}{4}$ inches and 9 inches diameter.

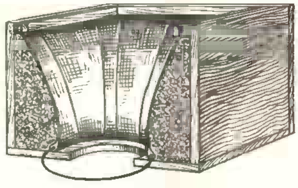


Fig. 6.—SECTION OF BOX BAFFLE.

The wood case is lined with slag wool held in shape by special fabric.

reproduction unless the loud speakers are properly mounted and housed. From a musical point of view, the practice of building dual speakers into a small cabinet full of wireless components inevitably leads to imperfect reproduction.

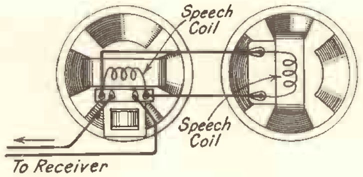


Fig. 7.—Circuit for P.M. Pair.

The output from the receiver is connected to the transformer on one speaker; the speech coils of both speakers are wired in parallel.

Comparative Sizes of Baffles

A large flat board with the speaker in the middle is one effective way of attaining the desired end; similarly, a like result could be obtained by using a very long and large trumpet. The diagram, Fig. 3, shows diagrammatically the relative sizes of a trumpet, a flat baffle and a box baffle. To give the same response value the trumpet would have to be 9 feet long, the flat baffle 5 feet square, and the box baffle 18 inches square and 10 inches deep.

The compactness and convenience of the box baffle is at once apparent, but a plain box is not effective, because it has a defined and very objectionable resonance of the order of 150 c.p.s. for an 18-inch box, because the sound waves are reflected from the walls and destroy the purity of the sounds—particularly at certain frequencies.

The "Howe" Box Baffle

It has been found that if a box baffle is lined with absorbent slag wool all traces of box resonance are eliminated and the purity and naturalness of reproduction are improved in a remarkable manner, there is no "boominess" and the sounds appear more crisp and life-like in every way.

The "Howe" box baffle, used extensively by the B.B.C., is the subject of patents. The sole licencees are Messrs. F. McNeill & Co. Ltd., 52 Russell Square, London, W.C.1, from whom all materials, kits of parts, or complete "Howe" box baffles can be had at a modest price that includes the necessary licence.

Dual Speaker Baffle

A "Howe" box baffle for use with a pair of balanced loud speakers is shown in Fig. 4, and has proved on test to be most effective and entirely satisfactory when used with high-grade loud speakers.

Dimensions of the box are given in Fig. 5—it is made chiefly of laminated board, ½ inch thick, with a reinforcing frame at the back. The interior is lined with "Slagbestos," a specially prepared form of slag wool, held in place by a special fabric.

The corner joints of the box are rebated or halved and strengthened with fillets where necessary—as shown in Fig. 5—and in section in Fig. 6, where the slagbestos is seen in place.

Building a Baffle Box

Readers who may wish to build their own box baffles should obtain their supplies with the necessary licence from Messrs. McNeill & Co., and should follow the detailed and clear instructions sent out with the kit of parts—which can be had for various sizes of speakers, either single or dual. The parts are not expensive, the improvement in the entertainment value of any set so equipped is well worth the small outlay.

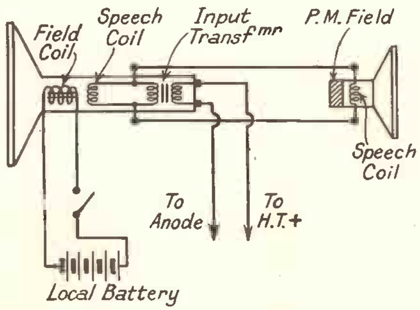


Fig. 8.—Composite Pair.

Circuit for a balanced pair consisting of one P.M. speaker and one with separately excited field.

Fitting up a Pair of Speakers

The best way to fit the speakers to the box baffle is to lay the box face downwards on the floor, put the speakers in place with the terminals facing each other, then put in place any condensers or resistances—as may be required by the design—and fix them temporarily with small screws.

Next, cut to length the various connecting wires and, where necessary, twist them together to reduce any risk of local pick-up or interference.

Arrange the leads from set to field coils — if any — and those to the input transformer so that they can be connected to insulated terminals at any convenient part of the box frame ; keep all the wires as short as possible and take them in the most direct manner towards the set ; then remove the speakers, solder the wires in place, fit the dust bags over the speakers and screw them very firmly into place. Drive the screws as evenly as possible, then tighten them up gradually, giving half a turn to each, so as to compress the felt ring uniformly and ensure that the speakers are really tightly fixed.

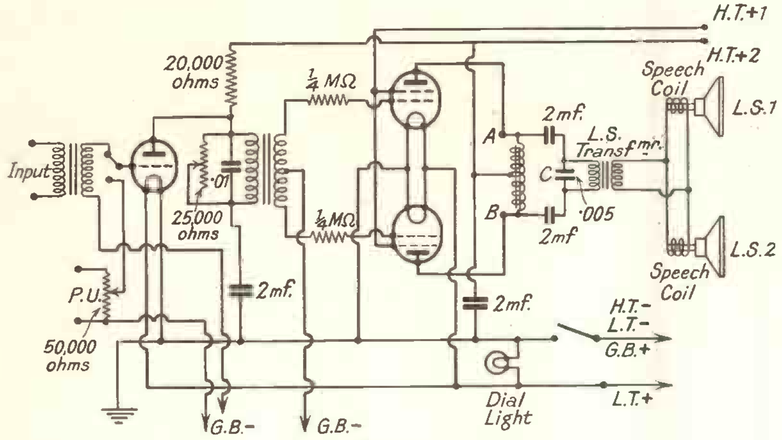


Fig. 9.—Battery Operated Amplifier.

Powerful but economical amplifier for dual P.M. balanced pair. Pentodes in push-pull give maximum volume with minimum H.T. consumption.

Dual Speaker Circuits

When a pair of speakers with permanent magnets are used the normal connections are shown in Fig. 7. The leads from the set are taken to the input transformer. The speech coils are connected in parallel.

Connections for a composite pair, consisting of one speaker with energised field and one with a P.M. field, are shown in Fig. 8. The field resistance can be excited by a local battery, which should be separately switched but controlled by the normal "on-off" switch knob.

The field is separately excited by the local battery, the leads from the set go to the transformer on the energised speaker, and the speech coils of both speakers are connected in parallel. This arrangement is sometimes useful when maximum output is required from an existing battery-operated set.

A similar arrangement can be used with a pair of field energised speakers, but it is not economical of current, and a better plan is to include the field coils in the circuit of the receiver, or to use a separate amplifying unit.

Field Excitation

The field coils of dual-balanced speakers can be arranged in several ways, according

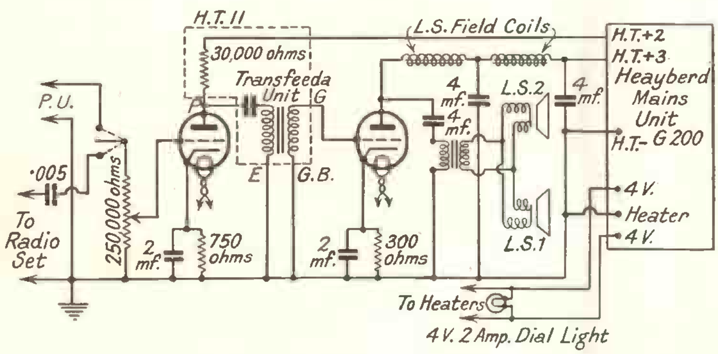


Fig. 10.—Amplifier for Dual Energised Speakers.

A.C. Mains Amplifier with speaker field coils as additional smoothing choke and output choke respectively.

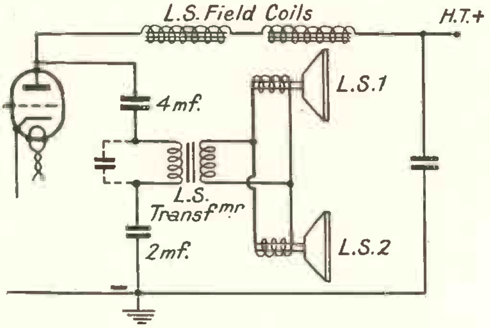


Fig. 11.—Field Coils as Output Choke.

The energised field coils can be used in place of an output choke in the anode circuit of the last valve when the general design of the set is suitable.

to requirements. The field coils may be connected in parallel or in series, according to the field coil resistance and supply voltage.

Normal resistances are 8 ohms, for use with 6 to 10 volt D.C. supply ; 2,000 ohms for use with 110 to 175 volts ; 4,700 ohms for 150 to 200 volts supply ; and 6,500 ohms for use on 200 to 250 volts supply.

Note that when two field coils of similar resistance are connected in parallel the current taken will be twice that taken by one speaker ; when wired in series the current will be the same as for a single speaker but the voltage required will be double.

Full Bass Response

In order to obtain full bass response it is necessary that the polarity of the field coils be correct, otherwise the higher notes will predominate. If the connections are not correct this can be detected by the ear and the field connections of one speaker only should be reversed.

Two speakers with dissimilar field resistances should not be connected in series.

Amplifier for Pair of P.M. Speakers

The circuit diagram, Fig. 9, shows an efficient battery-operated amplifier for a pair of P.M. balanced speakers.

The circuit is arranged for use after a receiver or in conjunction with a gramophone pick-up. Alternatively, the input transformer can be omitted and the amplifier coupled to the receiver by a small coupling condenser in the anode-grid lead. The H.T. — L.T. — lead on the amplifier should be connected to the earth lead on the receiver, or taken separately to earth.

The first L.F. valve is used as a driver to energise the push-pull transformer and to provide easy control of volume and tone for which purpose a capacity and a variable resistance are shunted across the input of the transformer. The use of high efficiency pentodes in push-pull provides enormous volume with reasonably low H.T. consumption. The amplifier, as shown, will not consume more than about 12 milliamperes—which is well within practicable limits. It is recommended that independent batteries be used for the amplifier, and the on-off switch interconnected with that on the set, or that a dial light be fitted as an indication that the amplifier is switched on.

Adjusting the Tone

Should the tone be considered too high pitched, due to the characteristics of the pentodes, a tone corrector consisting of a ·01 mfd. condenser in series with a 25,000 ohm variable resistance can be shunted across the output choke between the points A and B on the circuit diagram. The condenser C across the loud speaker transformer may be varied in value to attain the desired tone.

Components Required

The following components are required for the amplifier shown in Fig. 9.

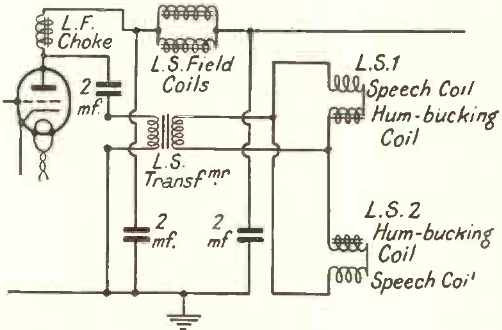


Fig. 12.—Energised Fields in Parallel.

Two energised field coils in parallel in the H.T + lead to the anode of output valve.

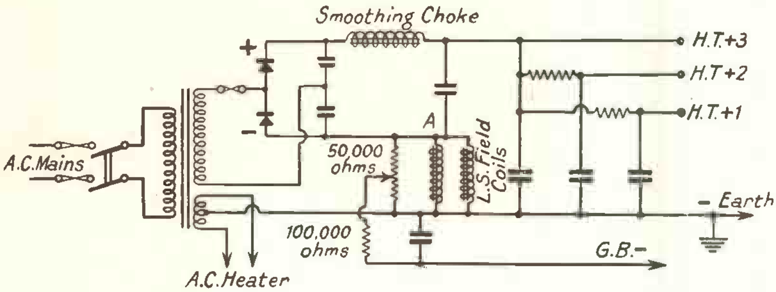


Fig. 13.—FIELD COILS IN NEGATIVE LEAD.

The voltage developed across the speaker field windings is used for automatic biassing. Values must be adjusted to suit specific conditions.

TRANSFORMERS.—1 Input L.F. Transformer ("*Lewcos*"); 1 "Push-Pull" Transformer AF5c ("*Ferranti*"); 1 Pentode Output Choke ("*Telsen*").

FIXED CONDENSERS.—4 Non-inductive Type 50, 2 mfd. ("*T.C.C.*"); 1 ·005 mfd., and 1 ·01 mfd. ("*T.C.C.*").

RESISTANCES.—2 ¼-megohm grid leaks with wire ends ("*Telsen*"); 1 25,000-ohm variable ("*Lewcos*"); 1 50,000-ohm variable ("*Colvern*"); 1 20,000-ohm-spaghetti ("*Lewcos*"); 1 Two-way Switch ("*Bulgin*"); 1 On-off Switch ("*Bulgin*")

VALVE HOLDERS.—1 4 pin, 2 5 pin ("*Lissen*").

VALVES.—1, L.2 ("*Mazda*"); 2, Pen. 220 ("*Mazda*").

LOUD SPEAKERS.—1 Balanced Pair F5, P.M. ("*Rola*").

BATTERY CORD.—1 7-way with "Wanderfuse" ("*Belling Lee*").

BATTERIES.—1 H.T. "Drydex," 120-volt, type H1015 ("*Exide*"); 1 Bias Battery, "Drydex," 15 volt, type H1002 ("*Exide*"); 1 L.T., 2-volt Battery, No. JZ4 ("*Exide*").

BOX BAFFLE.—"Howe," B.B.C. type ("*F. McNeill & Co.*").

Mains Amplifier

The circuit of an inexpensive mains amplifier for a balanced pair of speakers with field-excited coils, is shown in Fig. 10, and is capable of large outputs sufficient for large rooms or a small hall.

Provided it is separately earthed, this amplifier can be used with any form of receiver, or if a pick-up is used it can be employed as an electrical reproducer of gramophone records.

This circuit shows the two-field resistances used as a smoothing choke and an output choke respectively, the input transformer is capacity fed; the speech coils are connected in parallel, while the "hum bucking" coils are wired in series with the speech coils. The purpose of the "hum bucking" coils is to neutralise any hum generated as a by-product of the ripple voltage developed across the field resistances.

Recommended Components

The following components are recommended for this amplifier:—

VALVES.—1 41MHL, 1 41MXP ("*Cossor*").

L.F. TRANSFORMER.—"Transfeeda" ("*Benjamin Electric*").

MAINS UNIT.—No. G200 ("*Heayberd*").

FIXED CONDENSERS.—3 4 mfd. type 80; 2 2mfd. type 80; 1 ·005 mfd. type 50 ("*T.C.C.*").

LOUD SPEAKERS.—1 F.6; 1 F.7 2,000-ohms ("*Rola*").

BOX BAFFLE.—"Howe" Special Dual Kit ("*F. McNeill & Co.*").

RESISTANCES.—1 300-ohms strip wire wound; 1 750-ohm strip wire wound ("*Igranic*").

MAINS PLUG, FUSES AND SWITCH. ("*Bulgin.*")

POTENTIOMETER. — 250,000 ohms ("*Lewcos.*")

Incorporating Dual Speakers in Existing Sets

When it is desired to incorporate a dual set with energised fields in an existing A.C. mains set, the field coils can either be used as chokes in the anode circuit or can be treated as additional smoothing chokes.

In either case the values of resistance of the field coils must be suited to the details of the particular set. If an output choke is already fitted in the anode circuit, it could be removed and the field coils substituted and used as a choke, as shown in the skeleton circuit, Fig. 11; another plan is to wire them in parallel and insert them in the H.T. + lead to the anode as shown in the skeleton circuit, Fig. 12. In each case the values must be adapted to the set, the associated condensers must be added and care taken not to overload the output from the mains transformer.

Fitting Dual Speakers to Battery Sets

Speakers with separately excited field coils can be used with battery sets, but the best plan is to choose a pair with permanent magnet field excitation since these impose the minimum demand on the H.T. battery.

Celestion Dual Speaker

Celestion "Reetone" dual speakers consist of a pair of P.M. speakers of unequal size, mounted on a single baseplate, with the input transformer between them. The coupling between the speakers is so arranged that the treble is accepted by one and the bass by the other, thus together they cover the whole musical spectrum in a very satisfactory and highly realistic manner.

The power handling capabilities of this combination are considerable and are suited to powerful sets.

Celestion Matched Speaker

Whereas the "Reetone" dual speaker consists of two differently sized speakers, the Celestion "Reetone Matched" speaker consists of 2 units of equal size, but with diaphragms having dissimilar tonal response characteristics. These pairs are mounted on a single baseplate—which makes them very simple to fit, the transformer is mounted between the cones and is coupled in such a way that the mechanical resonances are staggered. This eliminates the tendency to boominess and greatly augments the output of the lower frequencies, with the nett result that reproduction is exceptionally pure and natural.

"Reetone" matched speakers are available with 2 P.M. units and are suitable for battery sets, others can be had with 1 P.M. unit and 1 energised field unit, or with 2 energised units. Any of them can be used on mains sets.

Energised Speakers as Components of New Set

When designing a new set it is possible to treat the field coils as components of the design, and in general the main smoothing choke can be reduced in value, usually to about 20 Henrys, and the field coils used as smoothing chokes.

Another plan, shown in Fig. 13, is to place the field coils in the negative lead—where they are quite effective as smoothing chokes and to use them as biassing resistances.

The field coil is placed between H.T. — and earth, thus making the spot A a certain voltage below earth. To enable the correct biassing voltage to be obtained a potential divider of at least 50,000 ohms must be connected across it, and if required several biassing voltages can be taken from it by means of suitable tappings, provided the grid circuits are separately de-coupled.

A condenser must be shunted across the biassing leads to earth to provide a low impedance path to earth for the L.F. speech currents, and a smoothing resistance of at least 100,000 ohms shunted across the condenser.

Importance of Adequate Power Supply

One very important matter for consideration when choosing any loud speaker, but more especially a good balanced pair, is the provision of adequate undistorted driving power.

The best results from most battery sets and many mains sets are usually obtained when the set is operated well within its maximum sound output. If in doubt, put a milliammeter in the H.T. negative lead and see how easily it will kick and register hopeless distortion if the set is overloaded at any part of the circuit.

Mains Units

Battery sets can be converted for mains operation by installing a H.T. mains unit and using the existing L.T. batteries. When this is done, it is practicable to provide a separate supply of power for energising the field coils of a dual speaker.

THE DESIGN OF A RADIO RECEIVER

By L. D. MACGREGOR

LET us suppose, for our example, that we are asked to design a receiver to comply with the following requirements :—

POWER OUTPUT.—For domestic use and possibly to feed one or more extra speakers (if required).

RANGE.—European stations—good sensitivity required.

SELECTIVITY.—Very good.

CONTROLS.—Single dial tuning, wave-change switch, volume and tone control.

QUALITY OF REPRODUCTION.—Very good.

CONSUMPTION.—Immaterial, as mains operated.

COST.—Hardly immaterial, but more towards moderate.

Referring to the article on " Receiver Design " (p. 909), we find that these requirements may be tabulated as follows :—

1B, 2C, 3B, 4B, 5B, 6A, 7B.

This will indicate the requirements. Reference to the descriptions under these headings will indicate the type of receiver.

We find accordingly that the output should be approximately 2 watts. Two or three stages of high-frequency (screened-grid) detector and L.F. (or output) will be required.

For selectivity a bandpass input and one or more tuned stages are indicated. The controls have already been specified, we know it is to be mains operated, and we need hardly worry about the cost, providing it is not made too expensive.

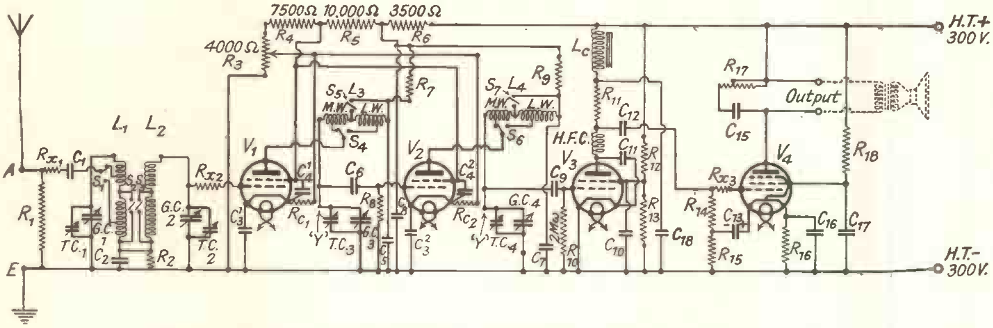


Fig. 1.—CIRCUIT DIAGRAM OF A TYPICAL FOUR-VALVE RECEIVER.

When designing a receiver it is useful to construct a diagram for each stage showing values and position for components. Various stages in the construction of the above circuit are shown in Figs. 7 to 11. The values of the various components are given on page 1066.

The Output Valve

Now how shall we proceed ? If we decide upon our output valve, then we can arrive at the remainder by stages.

A suitable valve for the purpose would be one of the A.C./Pentode class, such as the Mazda, A.C./Pen. We can assume a safe grid swing of about 20 to 30 volts peak, according to make of Pen. used.

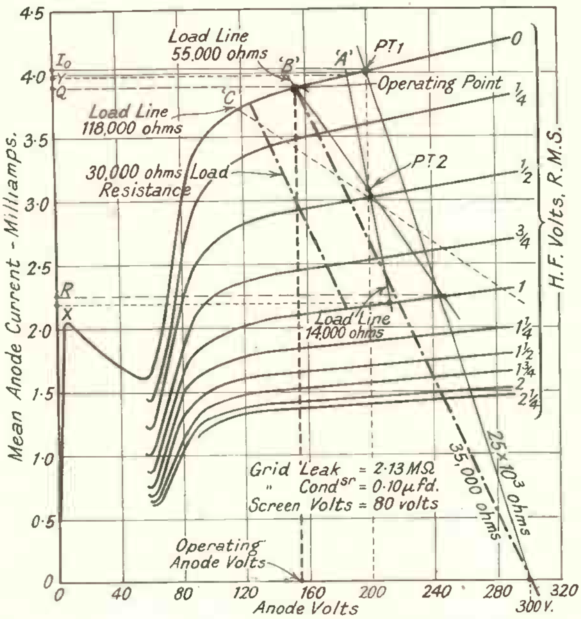
Transformer or Resistance Coupling

If a $3\frac{1}{2}$ to 1 transformer be employed to couple the previous stage to the pentode, then a peak volts of from 9 to 4 from the detector (according to output valve) will be required for full output.

On the other hand, if we have a valve which will deliver the 16 to 28 volts swing, *i.e.*, twice the peak A.C. volts, this could be coupled to the pentode *viâ* resistance coupling.

The course we will adopt will depend on the detector valve.

The transformer coupling would undoubtedly give greater sensitivity, but on the other hand the quality would not be quite so good as parallel-feed or resistance coupling—depending upon the detector characteristics. This will be more evident when we come to consider the detector stage.



[*By courtesy of the Osram Valve Co. Ltd.*

Fig. 2.—Typical Dynamic Characteristics of an Osram M.S.4B. Valve.

The Detector Stage

This stage requires careful consideration, as, should distortion occur here, it will of necessity be amplified in the succeeding stages, and up to the present no one has succeeded in designing a correcting device for distortion due to the detector valve.

Distortion on heavy passages—often attributed to overloading of the L.F. stages—is equally often as not due to distortion in the detector stage.

When considering the detector stage it is wise to estimate results on a basis of 100 per cent. modulation.

Dynamic Curves of Detector Valves

In Figs. 2, 3, 4, 5 and 6 we have dynamic curves of detector valves, by courtesy of Osram Valve Co. Figs. 2 and 3 are taken for a typical screened-grid valve working as a leaky grid or anode bend rectifier. Figs. 4 and 5 for a triode valve as leaky grid and anode bend rectifier.

These curves are dynamic, which is to say, that they have been taken under working conditions. From these curves the output from the valve may be easily determined for any given set of conditions.*

How to Use the Curves

If we start with the triode valve (Fig. 4) we shall find that it is in in many respects similar to the anode volts-anode current curves of an ordinary power output valve. Instead of having each curve drawn for a given value of grid bias, however, in this set of curves each curve corresponds to a given unmodulated H.F. input and there is a curve—marked 0—which corresponds to the valve with no H.F. input at all. Now these curves may be treated in very much the same manner as we treated the output valve curves in "Matching Output to Loud Speaker" (p. 707) and load lines, etc., may be drawn for various loads or resistance values.

Using Transformer Coupling

First let us consider the effect of using transformer coupling. Having checked the maker's particulars regarding transformers, we find that we should not pass more than 5 milliamps through the transformer primary windings. This means that our operating point (max.) will be 5 m.a. Accordingly, we draw from 5 m.a. a line to curve 0, giving point P.T.1. Our H.T. line supply is 300 volts, so we draw a line from P.T.1 to 300 volts and find that this line is equal to a resistance value of 40,000 ohms.

Value of Decoupling Resistance

This gives us the value of our de-coupling resistance, which will drop the voltage on the valve, so that it takes no more than

* P. K. Turner, *Wireless World*, Feb. 10th, 1932.

5 m.a. (If the transformer primary resistance is high this value may be subtracted from the 40,000 ohms, but generally it is sufficiently low to be negligible.) If we drop a perpendicular line from P.T.1 to anode volts line the point of intersection will give us the valve anode volts—in this case approximately 104 volts.

Where this line cuts the other curves will give us points such as P.T.2 and P.T.3 corresponding to different H.F. inputs or carrier values. The currents corresponding to these values are I_2 and I_3. We take I_3 corresponding to P.T.3 and to ½ volt R.M.S. input, and from point P.T.3 we draw a load line "B" equal to 85,000 ohms, which is approximately the impedance value of a good L.F. transformer primary at 50 cycles. This line will cut all the curves, but since we started at point P.T.3, we can only consider that part of the line which will be operative.

Point P.T.3 corresponds to a carrier value (unmodulated) of ½ volt R.M.S. If this carrier was modulated 100 per cent. the result would be equal to a variation between 0 and 1, which is equal to carrier value + or − the percentage modulation. This line cuts curve 0 at *a* and curve 1 at *b*, and the current values corresponding to these points are Q = 4 m.a. and R = 3·6 m.a. So that with no carrier we have 5 m.a. passing. With a carrier of ½ volt R.M.S. we have 3·8 m.a. passing, and if our carrier is modulated 100 per cent. we have the difference between 4 m.a. and 3·6 = 0·4 m.a. developed across our 85,000 ohm transformer load.

The Voltage Output

The total swing—positive and negative cycles, peak value—is equal to ·4 m.a. × 85,000 ohms, equal to 34 volts peak-*total* swing, which is equal to 17 volts peak or 9·8 volts R.M.S. output—for 100 per cent. modulation. The value for any percentage modulation can now be easily found and is equal to 9·8 × $\frac{\textit{reqd. percentage}}{100}$ for this case.

Distortion

Distortion, as far as the anode curve is concerned, may be checked in the similar manner as with power valves, and it is well to keep it as low as possible, as further allowance will have to be made in the subsequent stages and the sum total of allowances will, in time, mount up to a considerable figure.

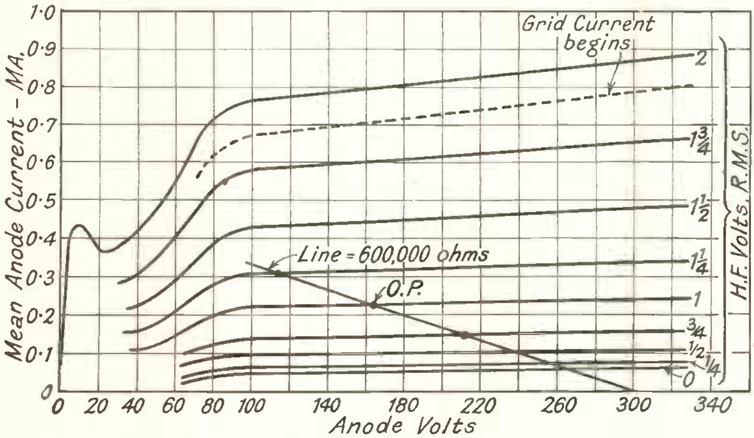


Fig. 3.—Typical Dynamic Characteristics of Osram M.S.4B. Valve as Anode Bend Detector.

Screen volts, 60; Grid bias, −3.

Resistance Loads

It should be borne in mind that whereas load lines of widely varying values may be drawn for *inductive* loads through the carrier operating point irrespective of the H.T. voltage, such will not be the case with resistance loads.

With resistance loads the load resistance value must be added to the de-coupling resistance value in order to determine the zero H.F. volts operating point.

Such a line for $40 \times 10^3 + 20 \times 10^3$ ohms is shown, giving an operating point P1 equal to anode volts—86v., with load line of 40,000 ohms drawn

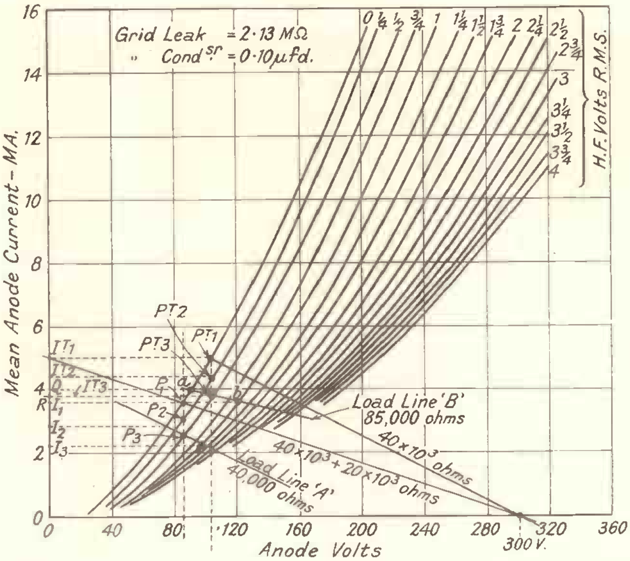


Fig. 4.—Typical Dynamic Characteristics of Osram M.H.4 Valve.

Grid leak, 2·13 megohm ; grid condenser, ·10 mfd.

through ½ volt R.M.S. H.F. input at point P.3.

With this valve at ½ R.M.S. input and 100 per cent. modulation we obtain a *change of current* of 0·6 m.a. across the 40,000 ohm load, giving us an output of : 24 volts swing = to 12 volts peak = to 8·5 volts R.M.S. L.F.

Output on Transformer Greater than with Resistance for same H.T. Volts

It is easily seen that, even with a 1 to 1 transformer, the output on transformer is greater than with resistance for the same H.T. volts. It is also easily seen that under these circumstances the maximum 100 per cent. modulated input that can be handled without distortion is approximately ½ volt R.M.S. If we could spare more volts we could work further up the curves and handle more input, but these are our present limitations.

Comparing the Curves

In like manner we can deal with the other curves. The curve we have been considering is that of a leaky grid triode. Comparing this with a leaky grid screened-grid valve we find that, for inductive load values between 14×10^3 and 55×10^3 ohms or for a resistive load of 30,000 ohms, we will obtain a "swing value" of 45 to 48 volts peak for 100 per cent. modulation with very little distortion indeed.

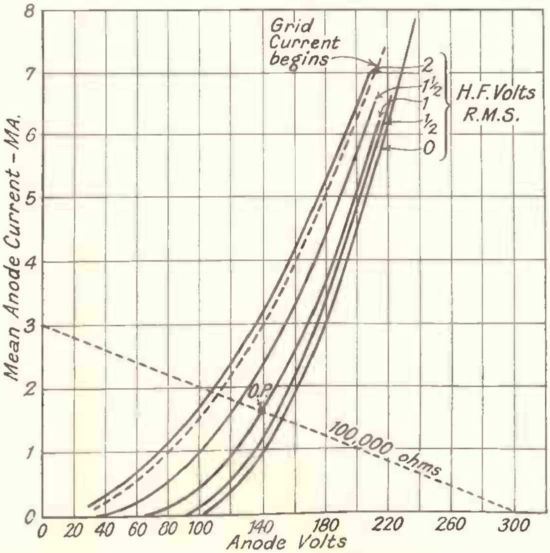


Fig. 5.—Typical Dynamic Characteristics of Osram M.H.4 as Anode Bend Detector at −3 volts Bias.

Anode Bend Rectification Curves

An examination of the curves for anode bend rectification will show that it is practically impossible to obtain a distortionless output—or even a 5 per cent. distortion—output with 100 per cent. modulation. A good value of output is obtainable, however.

Finding the Output from a Power-Grid Detector

Similarly, the output from a power-grid detector may be arrived at, and, provided the H.T. is available and the grid swing on the input not too low, practically distortionless output will ensue.

High-Tension Supply

Having considered our various detector stages we can next decide on the value of the H.T. supply and the valves to be used and then proceed with the design.

We can use the S.G. detector valve as leaky grid and, at an input signal voltage of ·5 volts R.M.S. H.F., load the pentode. Two high-frequency stages should give us all that we require, and accordingly we can use band-pass input, two variable-mu valves with tuned anode coupling, and couple the detector to the pentode by resistance coupling (for quality) or "Parallel-fed" transformer (for sensitivity). This will be the general outline of our circuit.

The Valves to be Used

We already have full particulars of the detector valve chosen—an Osram M.S.4B.—so we will decide on the Osram range and use two V.M.S.4 valves, one M.S.4B. and an M.P.T.4 pentode.

Fixing the Value of H.T. Supply

In considering this important point it will be necessary to find out the H.T. potential required for the last valve. In this case it is the M.P.T.4, and requires an anode voltage of 250. Referring to the maker's data we find that its anode curent at this voltage is approximately 32 milliamps. Assuming that our loud speaker transformer has a resistance of 600 ohms in its primary winding, the voltage drop across this will be $\frac{600 \times 32}{1000}$ ohms = 19·2 volts, bringing our required voltage up to 250 + 19·2 = 269·2 volts. Adding the bias value of − 11 volts we require 280 volts for this stage.

Is a Higher Voltage Necessary Elsewhere?

Before proceeding further with the power stage let us examine the requirements of the other stages and see if a higher voltage is necessary elsewhere. This is so because we shall require 300 volts in order to obtain good results from our detector stage, and so we may fix our H.T. supply voltage at 300 volts.

It may be thought that, by adding up the amount of current consumed by each valve, we might arrive at the required total current, but this is not the case, as there are potential dividers to be considered which consume current.

It is therefore wiser to proceed stage by stage and check the current consumption afterwards.

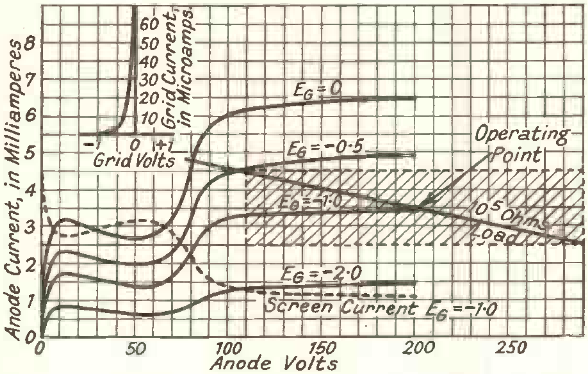


Fig. 6.—Average Characteristic Curves of Osram Type M.S.4B. Screen-Grid H.F. Amplifying Valve.

The Output Stage

Using an M.P.T.4 pentode we find that we shall require 250 volts at 32 m.a. for anode and 200 volts at approximately 5 m.a. for screen voltage, the necessary grid bias being 11 volts. The total consumption is therefore 37 m.a. For 11 volts bias we require $\frac{11}{\cdot 037}$ = approximately 300 ohms. This will give a voltage drop of 11 volts between cathode and − H.T., leaving a value of 300 − 11 volts, equal to 289 volts, which will have to be dropped accordingly for screen and anode.

The screen takes 5 m.a. at 200 volts, so we have 89 volts to drop here. The value of the resistance to do this will be $\frac{89}{\cdot 005}$ ohms = 17,800 ohms. The anode requires 250 volts, leaving 39 volts to be dropped. The output transformer resistance will have to be taken as being part of this dropping resistance. The total value will be $\frac{39}{\cdot 032}$ ohms = 1,219, say, 1,220 ohms. If we allow 520 ohms for transformer we shall require 700 ohms to make the voltage just right.

This may not be necessary, as the valve may stand the additional voltage quite comfortably. Still, we will consider the figure, as it may be necessary to add a de-coupling choke in the anode circuit.

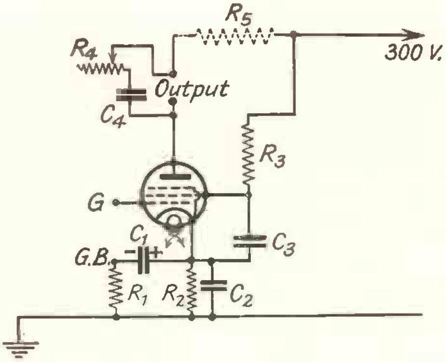


Fig. 7.—Pentode Output Stage Values.

R_1 (decoupling resistance), 50,000 ohms; R_2, 300 ohms; R_3, 17,500 ohms; R_4 (tone control resistance, 20,000 ohms; R_5, approx. 700 ohms (if required). C_1, 1 mfd.; C_2, 1 mfd.; C_3, 2 mfd.; C_4, ·01 mfd.

Resistance Wattage

The resistances will have a wattage dissipation, and this point should not be overlooked. The wattage may be calculated from I^2R = watts or I × V = watts, where I is the current in the resistance, R is the resistance in ohms and V is the voltage across the resistance equal to I × R.

Accordingly we shall require resistances which will have values and will carry wattages as follows:—

300 ohms—1·0 watt.
—for bias 11 volts.
17,800 ohms—0·5 watt.
—screen drop resistance.
700 ohms—1·0 watt.
—(if required).

As far as power is concerned this stage will require 300 volts at 37 m.a. equal to 11·1 watts.

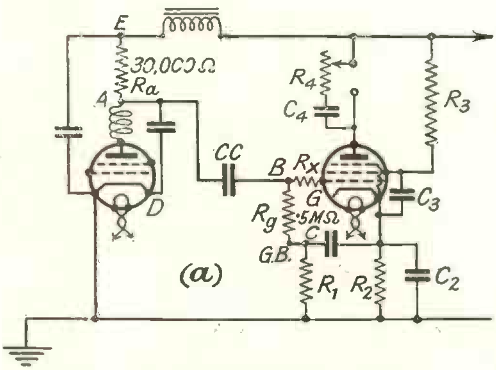


Fig. 8a.—Showing Coupling between Detector and Output Valve. Resistance Coupling.

Rg, ·5 megohm; CC, ·02 mfd. to ·05 mfd.; Rx, ·05 to ·1 (if required) H.F. grid stopper resistance.

The Detector Stage

With the M.S.4B. working as a detector we can, by referring to the curves, see exactly what current it will be taking. With a total resistance in the anode circuit of 35,000 ohms, at 300 volts, the valve will take approximately 3·9 m.a. with no signal. With ½ volt. R.M.S. H.F. input this will drop to 3·0 m.a. We have decided on an anode load, for L.F. purposes, of 30,000 ohms, which will leave us 5,000 for balancing voltage and de-coupling. A choke will almost certainly be necessary for de-coupling purposes—but we will deal with this point later.

The resistances will have to be of the 1·5 watt type to carry the current safely.

The screen voltage is given as 80 volts and the screen current average value is 1·2 m.a. In practice this may be found to vary somewhat, and adjustment should be made accordingly.

We shall require to drop 300 — 80 volts = 220 volts. The potentiometer method is the best, and if we allow this to take 5 m.a. we shall require a potentiometer of $\frac{300}{\cdot 005}$ = 60,000 ohms resistance capable of carrying 2 watts. This

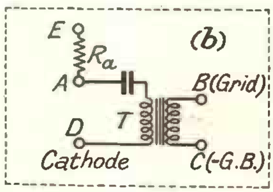


Fig. 8b.—Alterations to Resistance Coupling Connections when using Parallel Feed.

Ra should not exceed 30,000 ohms; transformer ratio, 3 to 1 or 3½ to 1.

value of 60,000 ohms will be divided into two portions.

The Values of the Potentiometer Sections

These may be worked out from particulars given in p. 460 of this publication. It will be observed that the potentiometer takes 5 m.a. and the valve 1·2 m.a. The top leg—as far as the screen connection—will therefore have to carry 6·2 m.a. and drop 220 volts. Its value will be equal to $\frac{220}{\cdot 0062}$ ohms = 35,500 ohms nearly. If we subtract this from 60,000 we obtain 24,500, which will be the value of the bottom leg of the potentiometer.

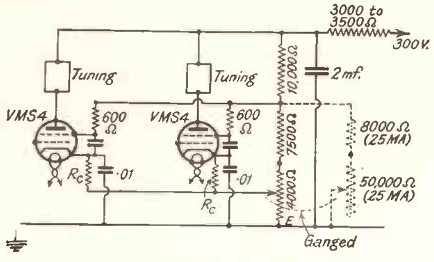


Fig. 9.—POTENTIOMETER CONNECTIONS FOR TWO V.M.S.4 VALVES.

Extra refinement to keep screen volts constant, shown as dotted lines. Value of Rc between 25 and 250 ohms.

De-coupling

If we consider sufficient de-coupling to be obtainable with a 10 or 20 thousand ohm resistance and a 2 mfd. condenser—giving a resistance-capacity reactance ratio of 5 to 1 and 10 to 1 respectively at 50 cycles, we can estimate the value of our choke at once. Dividing 10,000 by $2\pi f$ we have, for 50 cycles, $\frac{10{,}000}{314} = 30$ hys. approx. Therefore from 30 to 50 hys. should be sufficient. The current-carrying capacity need not exceed 5 m.a.

The By-pass Condenser

The anode resistance is 30,000 ohms. A ·0003 condenser at 5,000 cycles has a reactance of 100,000 and 50,000 ohms at 10,000 cycles. Therefore this value of by-pass condenser should not be exceeded. The shunting effect will be somewhat different from these values in view of the fact that the H.F. choke is virtually in series between the by-pass condenser and anode resistance. If a choke, such as the Lewcos H.F. choke, possessing an inductance of 0·2 hy. with 430 ohms resistance, is used it will present an impedance of approx. 6,300 ohms at 5,000 cycles and 12,500 ohms at 10,000 cycles.

To a considerable extent we can neglect the amount of high audio-frequency loss, which will be more or less compensated for in the pentode output stage.

The By-pass of Radio Frequencies

The reactance of such a choke is $1{\cdot}256 \times 10^6$ ohms at 300 metres and $6{\cdot}28 \times 10^5$ ohms at 600 metres. The reactance of the by-pass condenser is 500 ohms at 300 metres and 1,000 ohms at 600 metres. Therefore an H.F. signal on the anode of the detector valve will be reduced in the ratio of these figures. So for 300 metres we have a choke to condenser ratio of 2,500 to one, and at 600 metres a ratio of 65 to one. This is a very good ratio indeed, and if necessary the value of the by-pass condenser could be reduced.

The H.F. and Input Stage

This will depend largely upon requirements, but an excellent unit may be constructed by using band-pass input to the first valve, then utilising two variable-mu valves with " tuned anode " coupling between each other and the detector valve—all four tuned circuits being ganged.

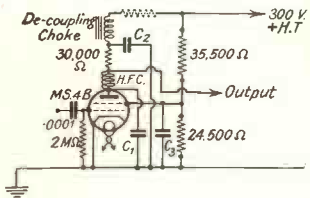


Fig. 10.—ARRANGEMENT OF POTENTIAL DIVIDER FOR M.S.4B. AS A DETECTOR VALVE.

Decoupling choke, 30–50 hys.; C_1, ·0003 mfd.; C_2, 2 mfd.; C_3, 2 mfd.

This method will solve much of the difficulty of providing volume control should valves of the ordinary S.G. type be used.

In general, a tuned circuit of a dynamic resistance value of 200,000 ohms is ample in the anode circuit of a single stage of variable-mu valve, whilst with two stages 100,000 ohms is ample. With these values the valves should oscillate on their own account with the volume control near maximum (*i.e.*, when the magnification is highest).

This will, to an extent, vary according to the load imposed by the detector valve, which in its turn will vary with frequency.

For the input the capacity-coupled band-pass would be the most simple to construct.

Details of the Coils

The coils, for a dynamic resistance value of 100,000 ohms approx. should have an inductance value of from 170 to 180 microhenries with an H.F. resistance of 11 ohms approx. To tune to 550 metres the tuning capacity would require to be ·0005 mfd. An inductance value of from 2,500 to 3,000 microhenries would be required for use on the long wavebands and the appropriate value of H.F. resistance may be computed from the formula:

$$\text{H.F. res. (ohms)} = \frac{\omega^2 L^2}{\text{Dynamic Res.}}$$

Should we decide to utilise the standard S.G. valve other than the variable-mu type, we shall have to limit the input H.F. voltage according to the load in the anode circuit, otherwise distortion would occur in the course of H.F. amplification, as in the case of L.F. amplification. This is illustrated in the accompanying sketch (Fig. 6).

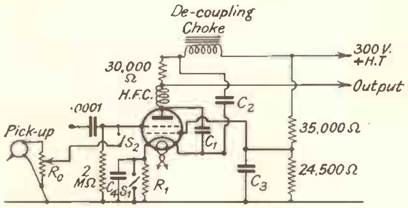


Fig. 11.—CIRCUIT DIAGRAM FOR USING PICK-UP.

R_0, 100,000 ohms; R_1, 250 to 320 ohms; C_4, 2 mfd. S_1 and S_2 are ganged switches made for pick-up.

Permissible Variation

Reference to Fig. 6 will show that at 200 volts H.T. only a variation of ± ·5 volt can be allowed with this valve with a dynamic resistance of 100,000 ohms in its anode circuit and a bias of — 1 volt. Greater variations than this will cause an excursion into the curved portion of the characteristic with consequent distortion.

The area of safe working with this valve is that enclosed by the shaded rectangle.

It will be obvious that the permissible load in the anode circuit is, to an extent, limited by the amount of grid swing. It is, of course, limited again by other factors, but these have been dealt with earlier in the course of this article.

The High-Frequency Valves

At maximum value of mutual conductance each valve will take 11·0 m.a. anode supply with 2·5 m.a. screen supply, making a maximum consumption of 27 m.a. at 200 volts for the two valves. In Fig. 9 we have a sketch of the potentiometer feeds to these valves with suitable values marked thereon. The potential comprising the three resistances, 10,000Ω, 7,500Ω and 4,000Ω will take approximately 10 m.a. and should be capable of carrying 1 to 1½ watts each. The 4,000 ohm is the biassing potentiometer and should preferably be graded more finely towards the end marked E. The value of Rc, which limits the minimum amount of bias, should be from 25 to 250 ohms. It is wise to start with the lower figure, and should the receiver be too prone to oscillation, *after adjustments have been made to the coils*, to increase the value of Rc until satisfactory working is obtained.

A Refinement that can be Added (Fig. 9)

For those who desire to add a refinement to keep the screen volts constant when the 4,000Ω potentiometer is varied, an arrangement is shown in dotted lines and the screen volts control is secured by a 50,000-ohm potentiometer ganged with the 4,000-ohm one. This arrangement is not absolutely necessary. The 3,000Ω to 3,500Ω resistance for dropping the H.T. volts should be of the 1 to 1½ watt type for normal connections and of the 2·5 watt type if the special screen voltage control is used.

The Magnification Obtainable

The magnification obtainable may be calculated for various arrangements of circuit from the simple formula: magnification (stage gain) = dynamic res. in anode circuit × mutual conductance *in amps per volt*.

RESOUNDING SUCCESSES

The **Lewcos** REGD.

POTENTIOMETERS

Write for leaflets N.79 and N.81 describing these outstanding components.

PRICES

VARIABLE POTENTIOMETERS
1,000 to 50,000 ohms .. 3/- to 3/6

HIGH RESISTANCE WIRE-WOUND VARIABLE POTENTIOMETERS
100,000 to 250,000 ohms. Constant increment 4/6

Increasing Increment 5/-

***500,000 ohms.** Constant Increment 8/-*

THE LONDON ELECTRIC WIRE COMPANY AND SMITHS, LIMITED, CHURCH ROAD, LEYTON, LONDON, E.10.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SERVICING MAJESTIC RECEIVERS

GRAMOPHONE PICK-UPS

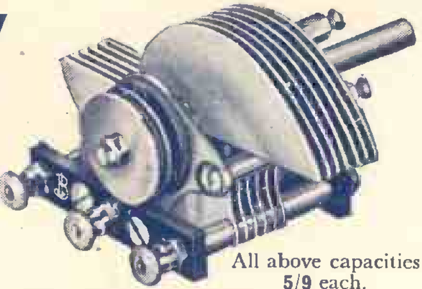
WIRELESS CONTROL OF MODELS

ELECTRIC GRAMO-PHONE MOTORS

1/-

Part 23

IN 32 WEEKLY PARTS



PART 23.

The makers of the V.M.S. 4-Valve give values of mutual conductance for various bias voltages as under:—

No.	Screen Volts.	Mut. Conductance.	G.B. Volts.
1	80	2·1	−1
2	,,	1·75	−2
3	,,	1·5	−3
4	,,	1·1	−4
5	60	1·6	−1
6	,,	1·0	−3
7	40	1·3	−1
8	,,	0·9	−2

Assuming our tuned anode circuit has a dynamic res. value of 100,000 ohms, then we may expect the following values of gain:—

No. 1	210	No. 5	160
No. 2	175	No. 6	100
No. 3	150	No. 7	130
No. 4	110	No. 8	90

If we tap our coil at, say, ½ or ⅓ from the top, thus making an auto-transformer of it, apart from enhanced selectivity the gain would be:—

No.	⅓ down.	½ down.
1	139	105
2	115	88
3	99	75
4	73	55
5	105	80
6	66	50
7	85	65
8	59·4	45

Showing a loss over the plain tuned anode.

A Practical Tip

Using the lowest value of R_c, test out the receiver on all wavebands. It may be found to be more prone to oscillation on, say, the long waveband, whilst in fair order on the medium. The long-wave tuned anode coils may then be tapped, as the tendency to oscillation is probably due to the dynamic resistance of the long-wave coils being too high. This is shown in the completed circuit sketch (Fig. 1).

Reducing Valve Load on the Coil

A small resistance, of approx. 600 ohms and small size, may be inserted between the grid of the first valve and its associated coil and will be found to be of some slight help in reducing the valve load on the coil.

Similarly a resistance, R_x, in circuit diagram, will slightly decrease the effect of the aerial loading on the first coil of the band-pass filter.

Capacity-Coupled Filter

A capacity-coupled filter is shown in the circuit diagram, and this could doubtless be improved upon by using a "mixed" filter, as described in the "Optimum 3-Valve Receiver" (p. 438), followed by coils of the Colvern K.G.O. pattern.

Working out the Magnification Obtainable

Those who are mathematically inclined can work out the magnification likely to be obtained from the band-pass circuit from the published formulæ. If we take it as being equal to the average coil magnification multiplied by ·8 we obtain a figure of 100. Allowing a generous loss value of 50 per cent. due to losses caused by aerial and other loading we can safely assume a value of 50.

The Approx. Amplification Obtainable

Coil input magnification	50 approx.
Valve mag. (per valve)	120 ,,
Detector mag.	18 ,,
Output valve (μ 100)	50 ,,

Total mag. approx. $= 50 \times 120 \times 120 \times 18 \times 50 = 6{\cdot}5 \times 10^8$, at full amplification.

Total mag. approx. (up to detector) $50 \times 120 \times 120 = 72 \times 10^4$.

From which it is reasonable to expect that an input signal to the receiver of $1{\cdot}5 \times 10^{-6}$ volts should load the detector valve and give full output.

Consumption of Receiver

From the preceding paragraphs it is easy to calculate the consumption of the receiver alone.

L.T. Consumption.	Volts.	Amps.	Watts.
4 valves at 4 volts, 1 amp. each	4	4	16
H.T. Consumption.	Volts.	M.A.	Watts.
H.F. Stages.			
2 valves at 27 m.a., 300 v.	300	27	8·1
Potentiometer at 10 m.a., 300 v.	300	10	3·0
Detector Stage.			
Anode, 4 m.a., 300.	300	4·0	1·2
Screen, 1·2 m.a., 300	,,	1·20	·36
Potentiometer, 5·0 m.a., 300	,,	5·0	1·5
Output Stage			
Anode, 32 m.a., 300	,,	32	9·6
Screen, 5 m.a., 300	,,	5	1·5
H.T. Total	300	84·2	25·26

H.T. Consumption.—84·2 m.a. at 300 volts . . =25·26 watts.

L.T. Consumption.—4·0 amps. at 4 volts . . =16·0 watts.

Receiver consumption . 41·26 watts.

Allow approx. 60 watts.

From these figures a suitable power pack can be designed and should prove to be of little difficulty if the particulars given elsewhere in this publication are followed.

A Useful Practical Tip

In the course of designing a receiver it will be found to be both useful and advantageous to construct a diagram for each stage showing values and positions of components, and from these to build up the final circuit. Such diagrams are given in Figs. 7 to 11, with the circuit diagram in Fig. 1.

It should be borne in mind that considerable care will have to be taken in constructing a receiver from a design, and it may be necessary to make certain modifications due to influences which may arise during the construction. Still, as it stands, the receiver should work well, and the mains operated S.G. valve will be found to be a most efficient detector and one which—for its type (leaky grid)—imposes the *least* load on the tuned circuit due to feed back or Miller effect.

The values of the components shown in Fig. 1 are as follows :—

Condensers.—G.C. 1, 2, 3 and 4, ganged ·0005 mfd. condensers ; T.C. 1, 2, 3 and 4, trimming condensers for above ; C1 = ·0002 μF. ; C2 = ·05 μF. ; $C^1 3$, $C^2 3$ = ·01 μF. ; $C^1 4$, $C^2 4$ = ·25μF. ; C5, C8, C7, C18, C17 = 2·0 μF. ; C6 = ·0001 μF. ; C9 = ·0001 μF. ; C11 = ·0003 μF. ; C12 = ·02 μF. ; C13 = from 2 to 4 mfd.* ; C15 = ·01 μF. ; C10 = 1·0 μF. ; C16 = 1·0 μF.

Resistances.—Rx1 = 600Ω approx. ; Rx2 = 600Ω ; Rx3 = ·05 to ·1 Mw ; R1, R15 = 50,000Ω ; R2 = 1,000Ω ; R3 = 4,000Ω Potr. ; R4 = 7,500Ω ; R5 = 10,000Ω ; R6 = 3,500Ω ; R7, R9 = 600Ω; R14, R8=·5MΩ ; R11 = 30,000Ω (max.) ; R12 = 35,500Ω ; R13 = 24,500Ω ; R16 = 300Ω ; R17 = 20,000 to 25,000Ω variable ; R18 = 17,500Ω ; R_{c1}, R_{c2} = 25Ω.

Valves.—V_1 and V_2 = V.M.S.4 ; V_3 = M.S.4B ; V4 = M.P.T.4.

* Use of a 25 mfd. is ideal (an electrolytic).

The dual wave coils are indicated by L. 1, 2, 3, 4 ; the ganged switching by S. 1, 2, 3, 4, 5, 6, 7 ; and the choke (30 to 50 hys.) by L_c. " Y " indicates where ·1 mfd. condensers may be inserted if insulation of gangs is doubtful.

SERVICING

MAJESTIC RECEIVERS, MODELS 15 AND 25

IF no signals whatever are received the first thing to do is to examine all external connections such as aerial, mains plug and switch, earth, etc. The aerial terminal will be found at the back of the chassis mounted on a small square of insulating material. See that the aerial is quite clear of the surrounding chassis and that no stray ends of wire are touching it. If so, it will earth the aerial and render the set absolutely silent.

Fig. 1.—THE FIRST STEP PRIOR TO THE REMOVAL OF CHASSIS.

The grub screws are loosened in control knobs so that they can be taken off. Valves should, of course, be removed before starting to remove the chassis.

The Valves

Next see that all valves are firmly pressed into their sockets and that none of the spring connections has come adrift. If the receiver still shows no sign of life run through the valves one by one. The best way to do this is to try a substitute set of valves which you know are good. From experience the G24 has been found to be the most likely cause of a breakdown.

THE MODEL 15 MAJESTIC

The Model 15 Majestic Chassis is a 4-valve superheterodyne designed to give the maximum efficiency with the minimum number of stages. In America this is called a five valve because the rectifier is included in the sum total of valves. The circuit is arranged as follows: Oscillator and first detector stage, intermediate frequency amplifier stage, second detector and pentode output stage.

How Grid Bias is Obtained

The necessary bias is obtained on the first detector and oscillator stage through a 10,000-ohm resistance between cathode and earth. The intermediate frequency amplifier is biassed through the volume control and a balance resistor of 264 ohms, which is contained in the volume control. The second detector is biassed through a 40,000 ohm resistor to earth in the cathode circuit.

The Volume Control

Volume control is obtained by a 11,500 ohm control which controls the bias of the oscillator, first detector and intermediate frequency stages. This control is so arranged in the circuit that in addition to

Fig. 2.—The Second Step is to Undo the Chassis Holes.

When these sets are delivered from the makers slips of wood will be found tightly wedged between the chassis and baseboard. These must be removed so that the chassis floats on the rubber pads provided. When replacing chassis bolts do not screw them up too tight.

controlling the bias of these two valves, it controls the input voltage to the pre-selector stage simultaneously, so that a balanced control is obtained.

Power Supply System

The power supply system consists of a power transformer, filter unit and dynamic speaker field. The filter unit contains two 8 mfd. dry electrolytic condensers, and the speaker field acts in the capacity of a choke.

There is no voltage adjuster on this chassis or the Model 25. They are suitable for operation on all A.C. voltages from 200–230, 50 cycles. If used on a higher voltage a suitable resistance can be obtained from the makers for a few shillings. No Majestic receivers are made for D.C. working.

THE MODEL 25 MAJESTIC

The Model 25 Chassis is designed on similar lines to the Model 15, but employs a greater number of tuned stages to give a uniformly high sensitivity and almost perfect audio-frequency response. The circuit is arranged as follows: pre-selector stage, oscillator, first detector stage, intermediate frequency amplifier stage, second detector (twin-power detection), and push-pull pentode power amplifier stage. From the foregoing it will be seen that, including the rectifier, this will be called a 9-valve receiver.

Grid Biassing Arrangements

In this receiver the radio frequency amplifier, first detector and intermediate frequency am-

Fig. 3.—The Chassis can now be Withdrawn.

To remove the speaker undo the four nuts holding it in position. The slot mentioned in the instructions for fitting a pick-up may be seen here.

Fig. 4.—ADJUSTING THE INTERMEDIATE FREQUENCY TRANSFORMERS.

It is only in extremely rare cases that these will need adjustment.

Fig. 5.—ADJUSTING THE ALIGNING CONDENSERS.

The pentode valve has been removed so that the operation may be clearly shown.

plifier are biassed by the volume control and a balance resistor of 160 ohms contained within it, the volume control being in the cathode circuit of these valves. The twin power detectors are biassed in their grid circuit by a 250,000 resistor to earth.

Volume Control

Volume control is obtained by a 6,500-ohm control in conjunction with the biassing of the valves mentioned above.

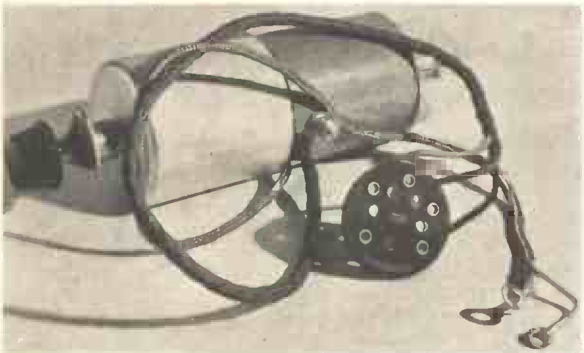


Fig. 6.—THE LONG-WAVE ADAPTOR.

The connector plate is well to the front here and particular care should be taken when fitting it. See that there is no bare wire at the point where the connecting wires enter the plate. Trouble has occasionally been encountered here as it causes a short to earth through these touching the chassis.

In this model the power supply system consists of a power transformer, filter unit and dynamic speaker field; filter unit contains two 8-mfd. dry electrolytic condensers, liberal choke and speaker field in addition.

SERVICE NOTES

If the receiver shows poor sensitivity examine the valves G51 and G51-S. If either of these shows a low

Fig. 7.—Drilling the Cabinet ready for the Long-wave Adaptor.

This hole must be drilled 2⅝ inch from top edge of cabinet and 1⅝ inch from back edge. In this position it will just clear the surrounding components.

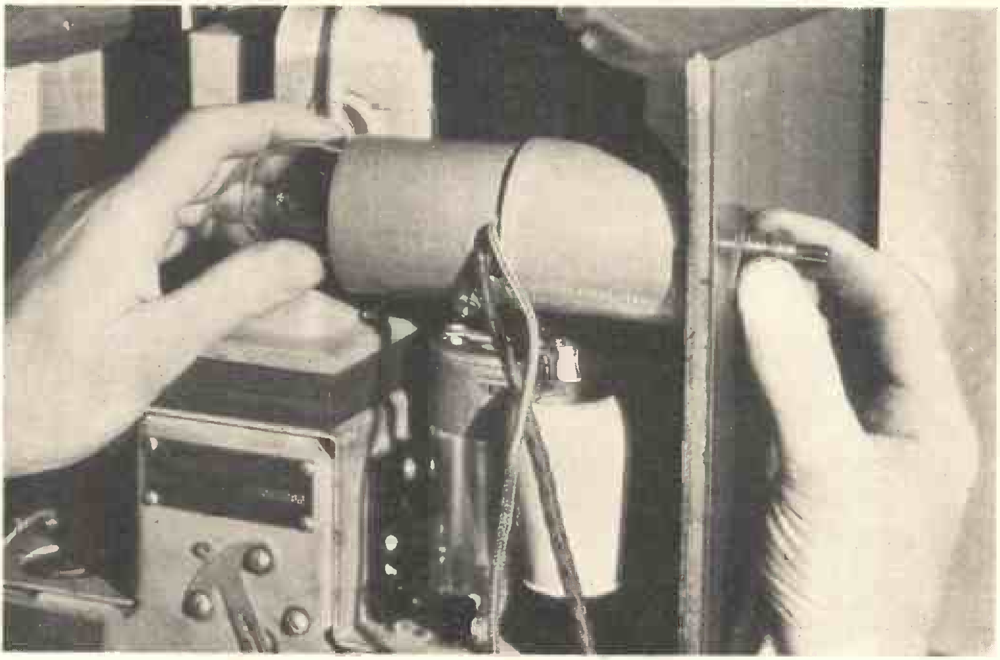


Fig. 8.—Fitting the Long-wave Adaptor in Position.

See that the metal-braided earth wire does not touch the metal coating of the adjacent valve, otherwise the set will be silent. It is just as well to secure it to the cabinet with a few insulated staples.

amplification factor the sensitivity of the receiver will be seriously affected. Always do this before attempting to re-align the condenser gang.

Checking Alignment

In checking the alignment of Models 15 and 25 the intermediate frequency transformers should not be aligned unless there is definite reason to suppose that they are out. It is only in very rare cases that they will need adjustment as all this is done before leaving the factory.

An output meter must be used if any of the above adjustments are needed.

Radio-frequency and Oscillator Alignment

(1) Tune in station in the vicinity of 1,500 kilocycles, or put output of local oscillator into receiver.

(2) Align R.F. stage, and oscillator tuning condenser. The R.F. stage and oscillator condensers are on the gang condenser.

Oscillator Tracking Condenser Alignment

(1) Tune in local oscillator to 600 kilocycles.

(2) Adjust both tuning control and tracking condenser simultaneously to give maximum signals as shown by output meter. This will be obtained by rocking tuning control across resonance point while adjusting tracking condenser to give maximum output at that point. This operation cannot be performed without local oscillator and output meter.

Now check the alignment previously made of the R.F. and oscillator aligning condenser in the neighbourhood of 1,500 kilocycles.

"On-Off" Switch

In these two models the "on" and "off" switch is incorporated in the volume control. Turning the knob to the left switches the receiver off. The first 15 degrees in a clockwise direction switches the receiver on and further movement increases the volume.

Continuity Tests

Table of continuity tests are given on pp. 1075 and 1078. In order to obtain the reading shown in these tables it will be necessary to rig up the continuity meter shown in Fig. 11.

THE MAJESTIC LONG-WAVE ADAPTOR

The Majestic Receivers, being of American origin were primarily designed

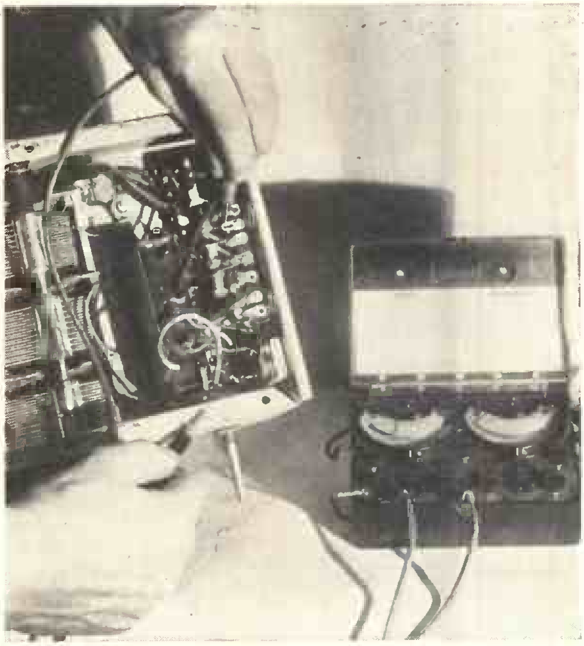


Fig. 9.—Making a Continuity Test.

for medium wave reception only, but in order to meet the demands of the English market it became necessary to provide a means of long wave reception. The Majestic Long Wave Adaptor was accordingly introduced.

The adaptor is suitable for use with Havenwood, Ellswood and Castlewood Models (all using Model 15 chassis), also Cheltenwood and Brentwood Models (Model 25 chassis).

How the Adaptor is Fitted

The adaptor is readily fitted to any of the above cabinets by the usual one-hole fixing method. Drill a ⅜-inch hole in a

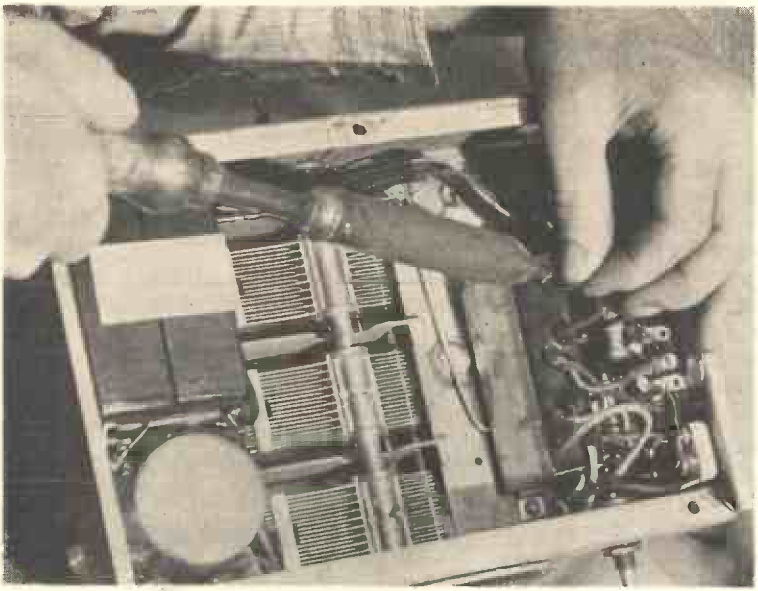


Fig. 10.—Unsoldering a Condenser Lead.

convenient position in the side of cabinet (in the case of Havenwood Models a template is provided as there is not much room to spare). Remove operating knob, lock nut and indicator plate from adaptor, insert screwed sleeve through hole, replace indicator plate and tighten lock nut. Replace knob. The whole job takes but a few minutes.

The Necessary Connections

A thin connector plate which slips over the legs of the G47 valve provides the necessary connections to the circuit. When placing this plate in position, between valve base and socket, take care that the side marked " top " *is* at the top. Mention of a small trouble encountered when fitting one of these may not be out of place here. See that there are no blobs of solder projecting from the connector plate which would touch the chassis, otherwise a quite unwelcome display of " fireworks "

may be provided.

Aerial and Earth Leads

The twin lead which has two tags at its end, the inner one being the aerial and the outer one earth, should be connected to their respective terminals on the chassis. The main aerial lead-in now goes to the terminal provided on the side of adaptor tube, while the earth connection remains as before.

Operating the Set with the Adaptor

The adaptor is now ready for use. With the knob in " short " position the set will operate as before. With knob in " long " position, long wave reception becomes possible without any further adjustment.

It will be found in practice that those long wave stations capable of reception can be tuned in at two distinct but widely separate points on the dial, namely, at from 1,000 to 1,150 kilocycles and from 700 to 550 kilocycles. This has an added advantage, as it will be found that should interference be experienced on one range the other may be comparatively free. It may be found, through unavoidable conditions, that local medium wave stations will be received even when the switch is set at " long." This will in no way interfere with long wave reception as it is confined to a different section of the dial from that on which the long wave stations come in.

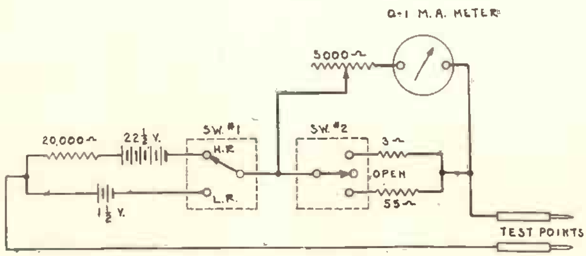


Fig. 11.—Diagram of Continuity Meter.

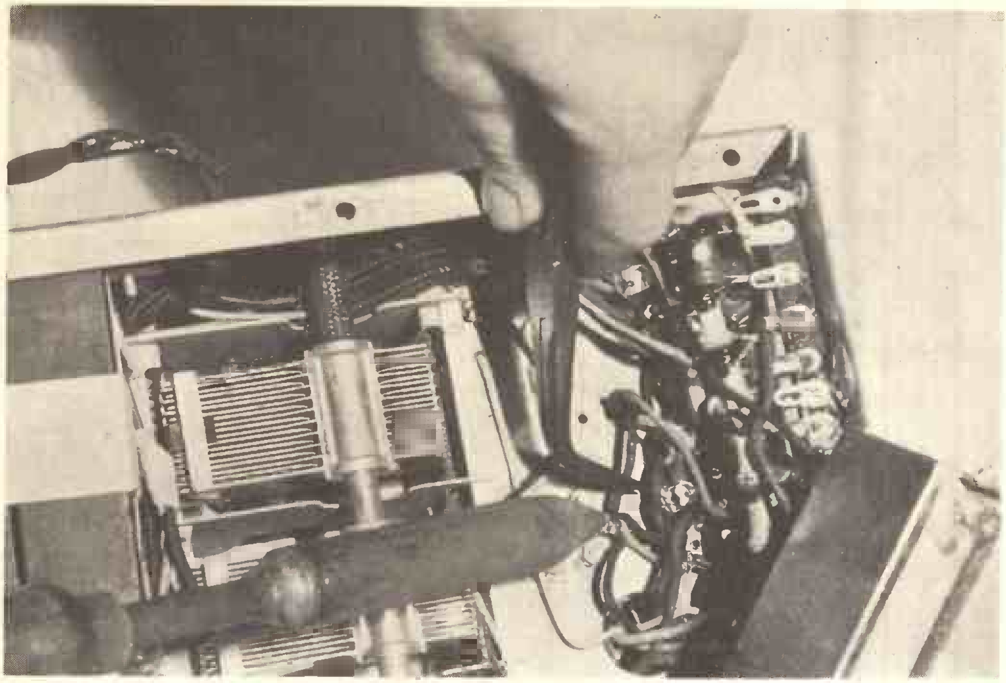


Fig. 12.—FITTING A PICK-UP.

Here we see the black lead which comes through the hole B being unsoldered from the tag D, the by-pass condenser having been removed. (See instructions for fitting pick-up.)

A Practical Point about Tuning

The method of logging a long-wave station is very interesting. Tune in a station which, as mentioned above, will be found at two points on the dial. Here it may be as well to mention that the tuning dials on Majestic receivers are calibrated in kilocycles. Note the kilocycle reading of the station at both points, subtract the smaller reading from the larger and divide by two. This will give the true kilocycle value of the station, which can then of course be identified by referring to a station chart.

To tune in any desired station it will first be necessary to know the oscillating frequency of the Majestic Adaptor (each one is clearly marked on the metal top). Add or subtract to or from this frequency the kilocycle value of the station required. The two answers will be the two dial readings of that station.

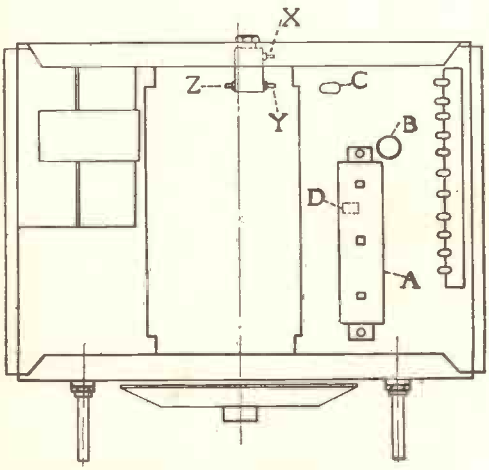


Fig. 13.—DETAILS FOR FITTING A PICK-UP.

FITTING A PICK-UP TO THE MODEL 15

In the Model 15 chassis no provision has been made for fitting a pick-up, but it is quite a simple and straightforward job to fit one.

Type of Jack to Use

It will be found that there is a slot at

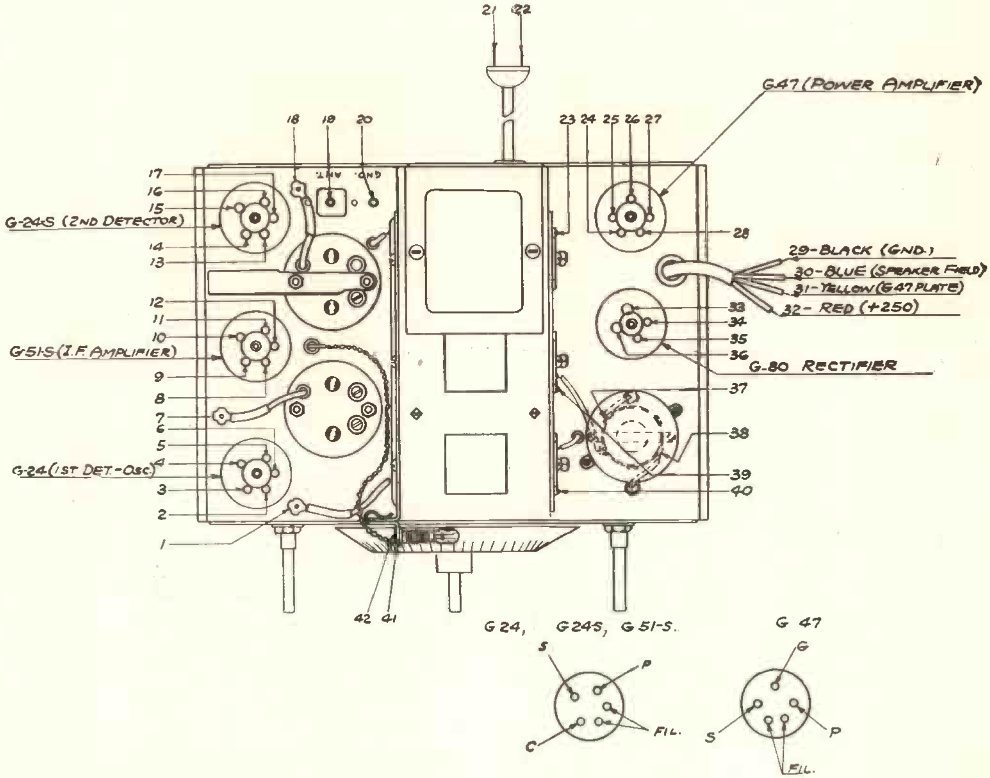


Fig. 14.—Continuity Chart, Model 15.

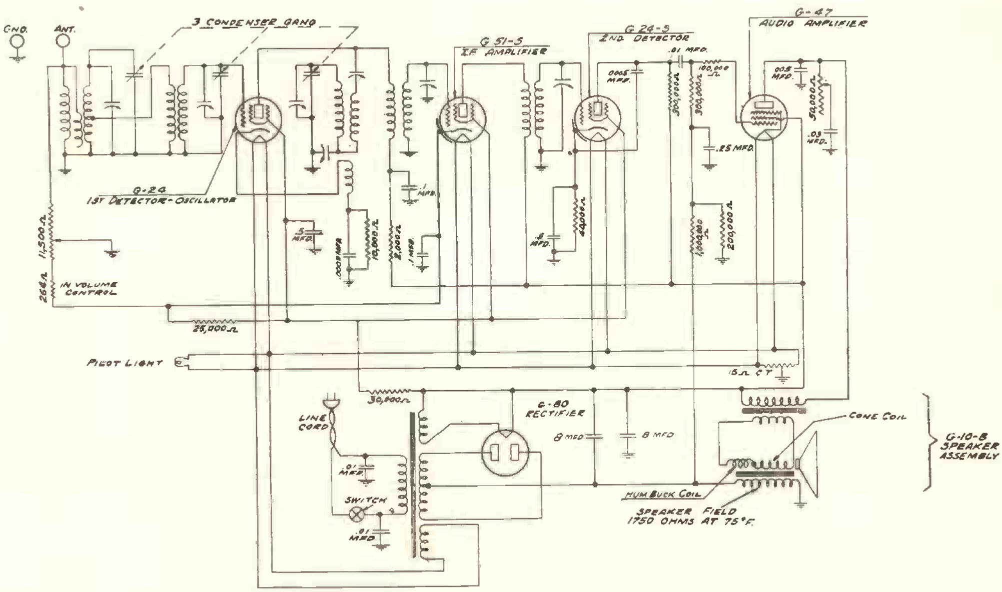


Fig. 15.—Theoretical Circuit Diagram of Majestic Model 15.

CONTINUITY TESTS FOR MAJESTIC MODEL 15

Use this Data in Conjunction with Fig. 14

ALL CONTINUITIES TO EARTH WITH VALVES REMOVED, SPEAKER DISCONNECTED AND VOLUME CONTROL IN MAXIMUM POSITION

Terminal No.	Continuity Meter Switch Position. No. 1.	No. 2.	Normal Reading.	If Meter Reading Differs Greatly, Investigate the following :
1	L.R.	3	0·5	Secondary of R.F. Transformer in Bottom of Chassis and Front Section of Gang Condenser.
2	L.R.	3	0·4 to 0·5	15-ohm Filament Centre Tap.
3	H.R.	Open	0·7	10,000-ohm Resistor and Oscillator Cathode Pick-up Coil.
4	H.R.	Open	0·5	25,000-ohm Resistor and Volume Control.
5	H.R.	Open	0·3 to 0·4	Primary of first I.F. Transformer, 2,000-ohm Resistor and ·1 mfd. Condenser in first Detector Oscillator Plate Circuit.
6	Same as Terminal No. 2		—	If both 2 and 6 indicate Open Circuit, the Centre of the 15-ohm C.T. Resistor is not Earthed.
2 to 6	L.R.	3	0·98	Lower Reading Indicated Open 2·5-volt Filament Winding in Power Transformer.
7	L.R.	55	0·3	Secondary of first I.F. Transformer and Aligning Condenser.
8	Same as Terminal No. 2.			
9	L.R.	Open	0·18 to 0·9	Volume Control and ·1 mfd.
10	Same as Terminal No. 4.			
11	H.R.	Open	0·3 to 0·4	Primary of second I.F. Transformer.
12	Same as Terminal No. 2.			
13	Same as Terminal No. 2.			
14	H.R.	Open	0·3 to 0·4	40,000-ohm Resistor and ·5-mfd. Condenser in second Detector Cathode Circuit.
15	Same as Terminal No. 4.			
16	H.R.	Open	0·05	Second Detector Plate 300,000-ohm Resistor ·0005-mfd. and ·01-mfd. Condensers.
17	Same as Terminal No. 2.			
18	L.R.	55	0·3 to 0·4	Secondary of second I.F. Transformer and Aligning Condenser. Sets provided with Local-distance Switch should be checked in " Distance " Position.
18	L.R.	Open	0·15 to 0·2	On Model 150 only.
19	L.R.	3	0·1 to 0·2	Primary of R.F. Transformer on Top of Chassis and Volume Control.
20	L.R.	3	Full	No Reading indicates Earth Terminal not Earthed.
21	H.R.	Open	0	Line Cord, Switch, ·01-mfd. Condenser to Primary of Power Transformer.
22	Same as Terminal No. 21.			
21 to 22	L.R.	3	0·2 to 0·3	Power Transformer Primary, Line Cord and Switch.
23	H.R.	Open	0	Rear Section of Gang Condenser and Oscillator Tracking Condenser.
24	Same as Terminal No. 2.			
25	H.R.	Open	0·3 to 0·4 and 0·4 to 0·5	Electrolytic Condensers, 30,000-ohm and 25,000-ohm Resistors and Volume Control. Note that the Readings vary according to the Polarity of the Test Leads. Use the Polarity giving the Lowest Reading (0·3 to 0·4).
26	H.R.	Open	About 0·03	100,000-ohm, 1 megohm, 200,000-ohm and 300,000-ohm Resistors and 0·25-mfd. Condensers.
27	H.R.	Open	0	·005-mfd. and 0·3-mfd. Condensers and Tone Control. About 0·3 with Speaker Connected.

Terminal No.	Continuity Meter Switch Position. No. 1.	No. 2.	Normal Reading.	If Meter Reading Differs Greatly, Investigate the following:
28	Same as Terminal No. 2.			
29	L.R.	3	Full	Speaker Cable.
30*	H.R.	Open	0·1 to 0·4	Electrolytic Condensers and High Voltage Secondary.
31*	Same as Terminal No. 27.			
32*	Same as Terminal No. 25.			
33	Same as Terminal No. 25.			
34	H.R.	Open	0·1 to 0·3	High Voltage and Winding Electrolytic Condensers about 0·9 with Speaker Connected.
35	Same as Terminal No. 34.			
34 to 35	L.R.	Open	0·7 to 0·8	High Voltage Winding.
36	Same as Terminal No. 33.			
33 to 36	L.R.	3	0·96	G-80 Filament Winding.
37	L.R.	3	0·7	Primary of R.F. Transformer under Chassis and Lower Half of Secondary of R.F. Transformer on Top of Chassis.
38	Same as Terminal No. 19		—	Wire from Aerial Post to Volume Control and R.F. Coil.
39	L.R.	3	0·5	Secondary of R.F. Transformer on Top of Chassis and Centre Section of Gang Condenser.
40	Same as Terminal No. 1.			
41	Same as Terminal No. 2.			
42	Same as Terminal No. 2.			

* See Table for Continuity Tests with Speaker Connected to Chassis.

Continuity Tests with the Speaker Connected to the Chassis

30	L.R.	Open	0·4 to 0·5	Speaker Field.
31	H.R.	Open	0·2 to 0·4	Same as 32 in other Table.
31 to 32	L.R.	Open	0·7 to 0·8	Primary of Output Transformer.

Checking Volume Control

19	L.R.	3	0·1 to 0·2	Volume Control at Maximum Volume.
19	L.R.	3	Full	Should give Full Reading at Minimum Position.
9	L.R.	Open	0·8 to 0·9	Volume Control at Maximum.
9	L.R.	Open	0·1 to 0·2	Volume Control at Minimum.

MODEL 15 CHASSIS
Table of Voltages to Earth

Valve. Purpose.	Type.	Fil. Volts. A.C.	Plate Volts. D.C.	Grid Volts. D.C.	Cathode Volts. D.C.	Plate Current. M.A.—D.C.	Screen Volts. D.C.
First Det.—Osc.	G-24	2·5	250	—	9	0·9	90
I.F. Amplifier	G-51-S	2·5	250	—	3·0†	7·0	90
Second Detector	G-24-S	2·5	250	—	9	0·17	90
Power Amplifier	G-47	2·5	250	−16·5*	—	32	250
Rectifier	G-80	5·0	—	—	—	54	—

* This cannot be measured with the customary 1,000-ohm per voltmeter because of the high resistance between the grid and earth. If there is any doubt about the pentode bias, check the 100,000 ohm, 1 megohm, 200,000 and 300,000 ohm resistors and 25-mfd. condenser in this circuit and be sure the speaker field voltage is correct, 112 volts. Also measure the pentode plate and screen voltages and if they are 250 volts, the plate current should be 32 m.a.

† This should rise to 42 when the volume control is turned to minimum.

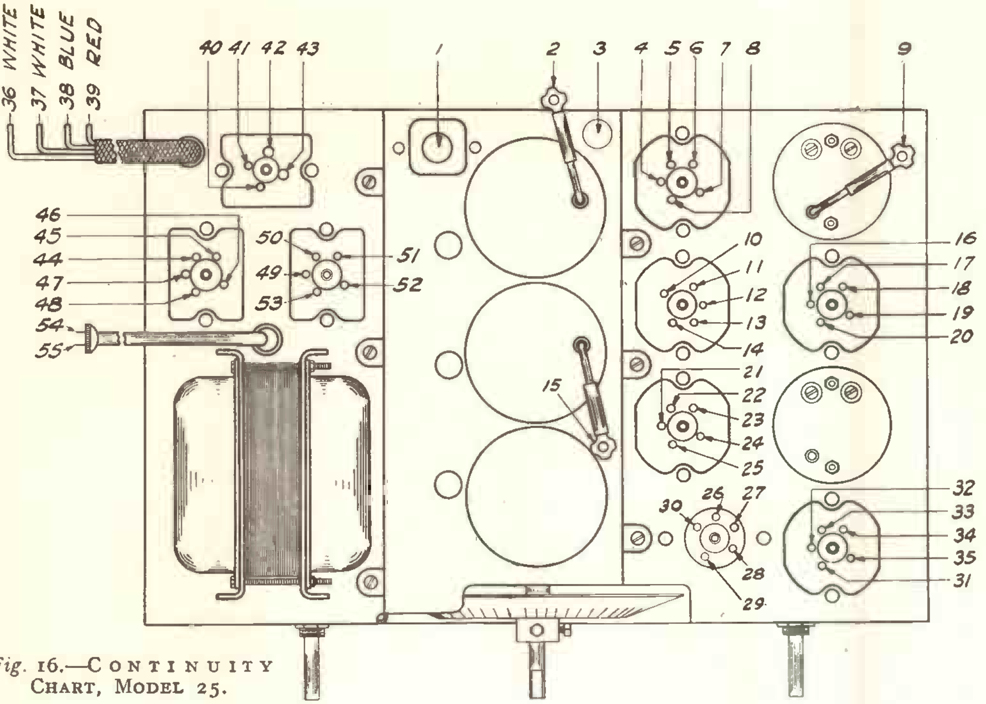


Fig. 16.—CONTINUITY CHART, MODEL 25.

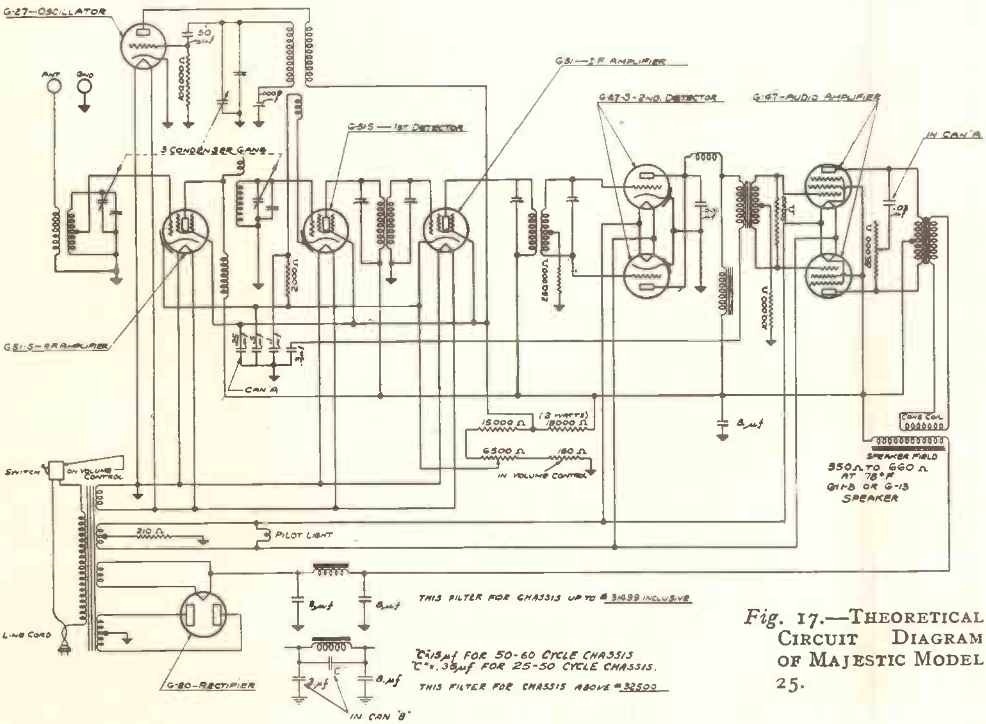


Fig. 17.—THEORETICAL CIRCUIT DIAGRAM OF MAJESTIC MODEL 25.

CONTINUITY TESTS FOR MODEL 25

Use this Data in Conjunction with Fig. 16

ALL CONTINUITIES TO EARTH WITH VALVES REMOVED, SPEAKER DISCONNECTED, VOLUME AND TONE CONTROL IN MAXIMUM POSITION

Terminal Number.	Continuity Meter Switch Position. No. 1.	No. 2.	Normal Reading.	If Meter Reading Differs Greatly from "Normal Reading," Investigate the following:
1	L R	3	·1 to ·15	Primary of 1st R. F. Transformer.
2	L.R.	3	·65	Secondary of R.F. Transformer, Gang and Aligning Condenser.
3	L.R.	3	1·0	No Reading Indicates Earth Terminal not Earthed.
4	L.R.	3	1·0	G-51 Filament Circuit not Earthed.
5	Same as Terminal No4.			
4 to 5	L.R.	3	·98	Indicates Open G-51 Winding.
6	L.R.	55	·15 to ·2	0·5 Mfd. Condenser and Volume Control.
7	H.R.	Open	·55	0·25 Mfd. Condenser, 15,000 Ohm and Volume Control.
8	H.R.	Open	·4 to ·45	Primary of Second R.F. Transformer, 8 Mfd. Condenser, 15,000 Ohm Resistor.
9	L.R.	55	·32	Secondary of 1st I.F. Transformer and Aligning Condenser.
10	Same as Terminal No. 7			
11	H.R.	Open	·4	Primary of 1st I.F. Transformer and Aligning Condenser, 8 Mfd. Condenser, etc.
12 & 13	Same as Terminal No. 4			
12 to 13	Same as Terminals Nos. 4 to 5			
14	L.R.	Open	·4	Oscillator Pick-up Coil, 2000 Ohm Resistor, 0·1 Mfd. Condenser.
15	L.R.	3	·47	Secondary of 2nd R.F. Transformer, Gang and Aligning Condenser.
16 & 17	Same as Terminal No. 4.			
16 to 17	Same as Terminals Nos. 4 to 5.			
18	Same as Terminal No. 6			
19	Same as Terminal No. 10			
20	H.R.	Open	·4 to ·45	Primary of 2nd I.F. Transformer and Aligning Condenser, etc.
21 & 22	Same as Terminal No. 4			
21 to 22	Same as Terminals Nos. 4 to 5.			
23	L.R.	3	1·0	No Reading Indicates Cathode not Earthed.
24	H.R.	Open	·12	100,000 Ohm Resistor Open or not Earthed, Shorted 50 Micro-Microfarad Condenser etc.
25	H.R.	Open	·55	Oscillator Plate Coil, 15,000 Ohm Resistor and Volume Control.
26 & 27	L.R.	55	·15	210 Ohm Resistor, 2·5 Volt Filament Winding.
26 to 27	L.R.	3	1·0	No Reading Indicates Open Filament Winding
28	L.R.	3	1·0	No Reading Indicates Cathode not Earthed.
29	H.R.	Open	·05	One Half of Secondary of Second I.F. Transformer and 250,000 Ohm Resistor.

Terminal Number.	Continuity Meter Switch Position. No. 1.	No. 2.	Normal Reading.	If Meter Reading Differs Greatly from "Normal Reading," Investigate the following:
30	H.R.	Open	·45	·001 Mfd. Condenser Shorted, R.F Choke, B Plus Choke, Primary of Input Transformer, etc.
31	Same as Terminal No. 30.			
32 & 33	Same as Terminals Nos. 26 and 27.			
32 to 33	Same as Terminals Nos. 26 to 27.			
34	Same as Terminal No. 28.			
35	Same as Terminal No. 29.			
36 & 37	L.R.	3	0	Earthed G-47 Plate or Speaker Cable.
38*	H.R.	Open	·35 to ·45	8 Mfd. Condenser, Power Choke, 80 Filament Winding.
39	H.R.	Open	·42	8 Mfd. Condenser, 15,000 Ohm Resistor, etc.
40	L.R.	55	·2 to ·25	One-Half of High Voltage Secondary.
41	Same as Terminal No. 40.			
40 to 41	L.R.	Open	·85	High Voltage Secondary.
42	Same as Terminal No. 38.			
43	Same as Terminal No. 38			
42 to 43	L.R.	3	1·0	G-80 Filament Winding.
44 & 47	Same as Terminals Nos. 26 and 27			
44 to 47	Same as Terminals Nos. 26 to 27.			
49 & 50	Same as Terminals Nos. 44 and 47.			
49 to 50	Same as Terminals Nos. 44 to 47.			
45 & 51	H.R.	Open	·45	See No. 30.
46	H.R.	Open	·15	One-Half Secondary of Push-Pull Input, Transformer, 100,000 Ohm and 500,000 Ohm Resistors.
47	See No. 44			
48	L.R.	3	0	Earthed Plate Terminal, 0·3 Mfd. Condenser.
51	See No. 45.			
52	Same as Terminal No. 46.			
46 to 52	H.R.	Open	·75	Secondary of Push-Pull Input Transformer, 500,000 Ohm Resistor.
53	L.R.	3	0	Earthed Volume Control. See No. 48.
54	LR.	3	0	Earthed Primary of Power Transformer.
55	Same as Terminal No. 54			
54 to 55	L.R.	3	·45	Off-On Switch; Primary of Power Transformer.

Continuity with Speaker Connected

All Continuities to Earth with Valves Removed, Speaker Disconnected, Volume and Tone Control in Maximum Position.

Terminal Number.	Continuity Meter Switch Position. No. 1.	No. 2.	Normal Reading.	If Meter Reading Differs Greatly from "Normal Reading," Investigate the following:
48 & 53	H.R.	Open	·45 to ·50	Primary of Output Transformer. Also see No. 30.
38 & 39	H.R.	Open	·45 to ·50	Speaker Field. Also see No. 30.

* Note that the readings vary according to the polarity of the test leads. Use the polarity giving approximately the same results as indicated above.

MODEL 25

Table of Voltages to Earth

Valve Purpose.	Type.	Fil. Volts. A.C.	Plate Volts. D.C.	Fil. to Earth. D.C.	Cathode Volts.	Plate Current M.A.—D.C.	Screen Volts.
R.F. Amp. . .	G-51's	2·5	260	—	3·5	5·0	90
1st Det. . . .	G-51's	2·5	260	—	8·0	1·0	90
Osc.	G-27	2·5	90	—	—	3·5	—
I.F.	G-51's	2·5	260	—	3·5	5·5	90
2nd Det. . . .	G-27's	2·5	115	—	—	14	—
2nd Det. . . .	G-27's	2·5	115	—	—	14	—
Power Amp. . .	G-47	2·5	245	−16·5	—	32	260
Power Amp. . .	G-47	2·5	245	16·5	—	32	260
Rectifier . . .	G-80	5·	400	—	—	120 (T	otal)—

D.C. First Condenser 385 volts.
D.C. Second Condenser 330 volts.
Line Voltage 115 volts.

Speaker Field 70 volts.

Volume Control—Maximum.

the back of the chassis; it is sometimes covered by a label, so may have been unnoticed. This slot is used to accommodate a jack. The jack recommended is an Igranic Midget Jack, No. P72, costing 1s. 6*d*. Any other jack of similar type will do but, *this is very important*, it must not project more than 1 inch into the chassis, otherwise it will foul the moving vanes of the condenser gang. The jack plug must open the circuit when inserted and close it when withdrawn.

The chassis must be withdrawn from the cabinet, first taking care to remove valves in case of accidents. Turn chassis bottom up, noting that condenser vanes are fully " in mesh."

The by-pass condenser A must now be unscrewed from chassis, taking great care that no connections are broken. Unsolder the *black* lead which comes through the hole B from tag D (Fig. 13), (originally covered by the condenser), and connect to terminal Y on jack. As an Igranic jack is shown in the illustration, terminals X and Y are both connected to tag C. Replace by-pass condenser and make sure that all connections are sound.

Using the Pick-Up

The gramophone pick-up, which must be one with a high impedance, may now be connected to the jack plug. Simple insertion of the plug will now instantly make the set ready for gramophone reproduction. In order to avoid radio interference turn radio volume control to minimum position and de-tune from local station. Of course the usual volume control is required if not incorporated in the pick-up apparatus.

The diagrams and Continuity Test Tables are reproduced by courtesy of the Majestic Electric Co. Ltd.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XVII—REPRODUCTION OF WIRELESS SIGNALS

REPRODUCTION of wireless signals can be divided into two classes—instantaneous reproduction, as in the case of an ordinary receiver and head-telephones or a loud speaker—and permanent reproduction in the form of some record, be it a steel tape (Blattnerphone method), a gramophone disc, or a film carrying a sound track.

Instantaneous Reproduction

Let us consider first of all the methods of instantaneous reproduction. This is carried out with the help of either head-telephones or loud speakers.

The main principle underlying the working of telephones is that of the magnetic effect of electrical currents. Of this effect I have already spoken in a previous article. But there is one point I should like to raise again, and that is the question of magnetic polarity of a loop of wire carrying a current.

Magnetic Polarity of a Loop of Wire Carrying a Current

When the magnetic effect of electrical currents was first studied it was thought at the time that current flows from the positive terminal of a cell to the negative terminal. This assumption is shown in Fig. 1. The polarity of the loop is shown as south. This polarity cannot be disputed as it has been tested by attraction or repulsion of magnetic poles. But the direction of current is shown wrongly. We know now that current flows from the negative terminal of a cell.

Thus, if we show the real direction of current, as in Fig. 2, we shall find that if a current flows in a loop of wire in an anti-clockwise direction (in direction opposite to the movement of the hands of a clock) the loop shows a south polarity at the observed side.

Similarly, as can be seen from Figs. 3 and 4, a loop of wire in which the current is flowing in a clockwise direction will show a north polarity. In order to bring old text-books up to date, reverse the direction of current flowing from cells, so that they

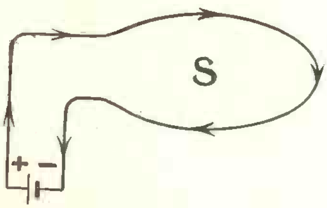


Fig. 1.—Wrong Direction of Current

It was thought at one time that current flows from the positive terminal of a cell to the negative terminal.

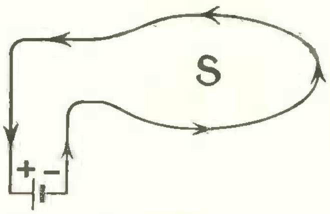


Fig. 2.—Real Direction of Current.

Here the current is shown as flowing from the negative terminal to the positive terminal.

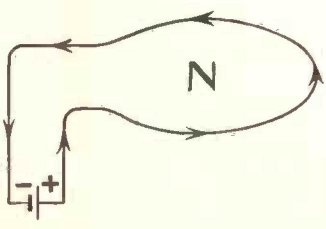


Fig. 3.—Wrong Direction of Current.

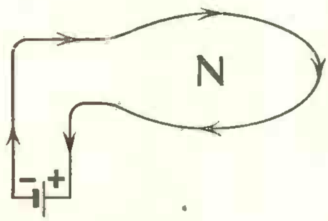


Fig. 4.—Real Direction of Current.

are shown as starting from the negative terminal.

Polarity of Coils round a Permanent Magnet

If we take a permanent steel magnet and clamp to it two iron cylinders to serve as cores of coils we shall have an arrangement such as shown in Fig. 5B. The permanent magnet will communicate its polarity to the iron cores by contact so that, when no current is flowing through the coil, the left hand piece of iron will, say, possess a south polarity and the right hand one will possess north polarity. If we connect the coils on each core, as shown, to the cell, we shall find that the coils will have the same polarities as the magnet, and therefore at the poles of our now electro-magnet we shall have the magnetic effect of electrical current adding to the magnetism of each pole.

Fig. 5A.—WORK IT OUT YOURSELF. Remembering that the centre terminal of battery is positive.

Reversing the Cell Connections

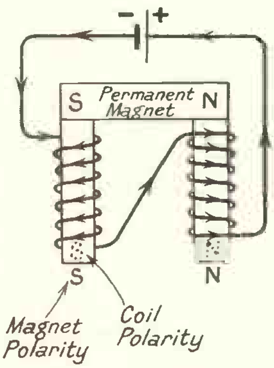


Fig. 5B.—POLARITY OF COILS ROUND A PERMANENT MAGNET.

If the cell connections now be reversed, as shown in Fig. 6, the polarity of the coils will be different to that of the magnet poles. If the latter be greater their magnetism will be weakened by the coils and the final effect will be smaller.

This shows us a method by which we can add or subtract from the magnetic intensity of a permanent magnet.

Attraction of a Soft Iron Diaphragm

Let us place a soft iron diaphragm in front of such an electro-magnet. In the first place, let us consider a magnet without the coils, as can be seen in Fig. 7. Since the magnetic intensity of the two poles is constant, thanks to the permanent magnet, the iron diaphragm will be slightly attracted to the poles, and thus displaced from its neutral position. This diaphragm can be so clamped in position that, while it is being attracted to the poles, it can never be pulled in far enough to touch the magnet poles.

Effect of Current Flowing in the Coils

In Fig. 8 we see the coils in position and the current flowing so as to add to the magnetic intensity of the magnet poles. The latter will therefore attract stronger and the diaphragm will come a little nearer to the poles.

Reversal of Current

With the reversal of the current (Fig. 9) the magnetic intensity of the poles will be weakened and the diaphragm will be once more nearer to its neutral position.

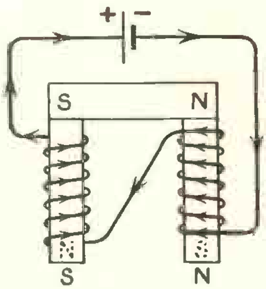


Fig. 6.—SHOWING THE CELL CONNECTIONS REVERSED.

Source of Alternating E.M.F. instead of a Cell

If, instead of a cell, we connect our windings to a source of an alternating E.M.F., which will mean that the direction of current will be reversed once every cycle, and the current strength will undergo periodical variations during each half-cycle, the magnetic intensity of the poles will therefore vary throughout the half-cycle, and will be alternately weakened and strengthened each half-cycle. This means that the diaphragm will begin to vibrate about its mean position, flying now towards the poles, now away from them, on account of its own inertia.

If the frequency of the alternating current be too high, and assuming that the windings did allow a high-frequency current to pass unimpeded (as you already know this is not the case), the diaphragm, on account of its inertia, could not possibly follow such rapid variations and would remain more or less stationary. Before it could fly one way it would be pulled the opposite way. Again, assuming that even if the diaphragm could follow such rapid variations mechanically, the note emitted by it would be so high as to be inaudible. Thus, it is clear that if the diaphragm is to vibrate properly and to cause audible sound wave in the surrounding air, it must vibrate within the audible limits of frequency.

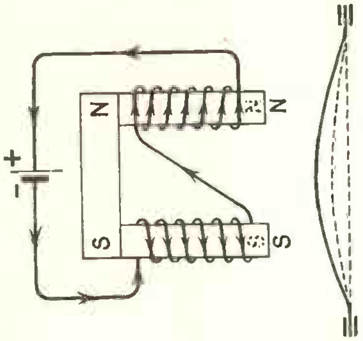


Fig. 8.—Showing Effect of Current Flowing.

Iron Diaphragm Vibrates in the same way as the Microphone Diaphragm

But, if we place such an arrangement of magnets and coils across the output terminals of a wireless receiver, we shall have the output current flowing through the windings. This current, as we already know, is the current that has been dealt with by the detector, and is of such a form that the self-inductance of our windings will convert it, with the help of the self-capacity of the windings, into a current identical with the microphone current and the iron diaphragm will be made to vibrate in the same way in which the microphone diaphragm has been vibrating.

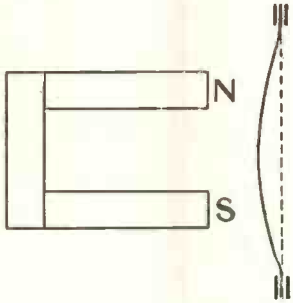


Fig. 7.—Showing the Attraction of a Soft Iron Diaphragm by an Electro-Magnet

How a Telephone Receiver is Constructed

And this is how a telephone receiver is constructed. It consists of a permanent magnet to which are clamped two iron pole pieces. The latter carry two coils in series, and the coils are connected to the output terminals of the receiver. In the case of head-telephones two earpieces are used, the coils of which are connected in series.

It does not matter if such head-telephones are connected directly to the output terminals of a receiver or through a transformer (a step-down one), the action will be the same, and the telephone diaphragm

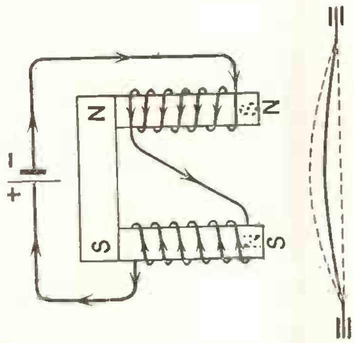


Fig. 9.—Showing Effect of Reversal of Current.

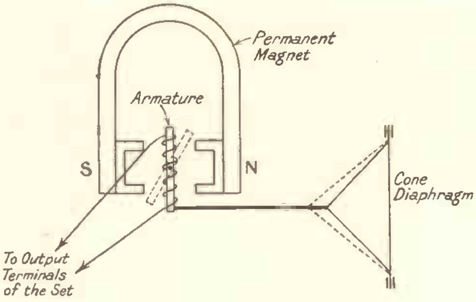


Fig. 10.—A Balanced Armature Type of Loud Speaker with Coils wound around the Armature.

will vibrate in precisely the same way in which the microphone diaphragm has been vibrating at the transmitting end.

Large amount of Self-inductance Necessary

As you already know from our discussion of the work of the detector circuit, the telephone windings must possess a great deal of self-inductance, and for this reason we must have large coils of fine wire. But these coils, being large, contain a great deal of length of wire and their resistance is therefore high. High resistance in the telephones is the last thing we want. It is a necessary evil in order to obtain a large amount of self-inductance. Thus it is clear that the well-advertised high resistance of telephones is not a desirable virtue by itself, but merely means that the telephones possess the necessary amount of self-inductance.

Low-Resistance Telephones

It is possible to use low-resistance telephones, *i.e.*, telephones with a smaller number of turns in the windings, provided they are connected to the output terminals of a receiver not directly, but through a telephone (step-down) transformer. It is then the self-inductance of the transformer windings that comes into play and compensates for the lack of self-inductance of the telephone windings.

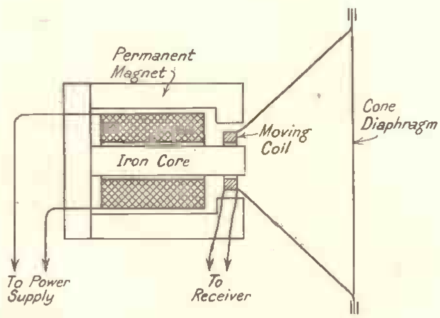


Fig. 12.—Moving Coil Loud Speaker.

Advantage of Using Low-Resistance Telephones with a Transformer

There is a considerable advantage in using low-resistance telephones with a transformer. In the first place, a current flows through the telephones only when signals are being actually received. Were the telephones connected directly in the anode circuit of the last valve, the normal anode current would be flowing constantly through them. Such a current, should the telephones be connected the wrong way round, can completely demagnetise the permanent magnet.

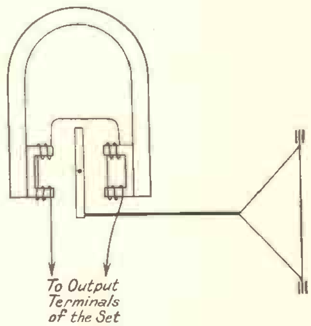


Fig. 11.—This shows a Balanced Armature Loud Speaker with Coils placed on the Pole Pieces of the Magnet.

Since there are fewer turns in the windings of low-resistance telephones, each turn can be much better insulated and the whole thing can be made much more robust. The last, but not the least, advantage is that the voltages across the windings are much smaller and therefore there is less danger of insulation breakdown.

Development of Loud Speakers

In the early days of broadcasting the horn loud speaker was a direct development of telephones and consisted of a glorified telephone " ear-piece " with a tin horn attached. Some of the firms, in order to avoid self-resonance, made the horns of wood, but this did not help much. This type of loud speaker was soon discarded and its place was taken by the so-called cone speaker, which had a moving armature driving the cone.

Cone Loud Speakers

There are three types of the better known of such loud speakers, and they are, the reed type, the inductor type and the balanced armature type. The principle of working is the same in all the three types, and it is only the manner in which the armature moves that differs.

Balanced Armature Loud Speaker

In Fig. 10 a balanced armature type of a loud speaker is shown. This is, as you can see, a piece of iron balanced in the

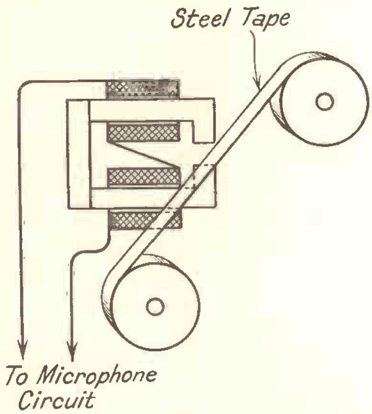


Fig. 14.—THE BLATTNERPHONE METHOD OF PERMANENT RECORDING.

centre in the space between the pole-pieces of a permanent magnet.

As the Figs. 10 and 11 show, the coils connected to the output terminals of the set can be wound around the armature itself or placed on the pole pieces of the magnet. The action is the same in both cases. The intensity of the magnetic field in the gap is varied and the armature, under the influence of magnetic induction, is compelled to move whenever the intensity of the magnetic field is changing. A connecting rod is attached to the moving armature which is thus enabled to drive the cone diaphragm.

Reed Armature Loud Speaker

In the case of a reed armature, the latter is fixed in front of magnet poles at one end

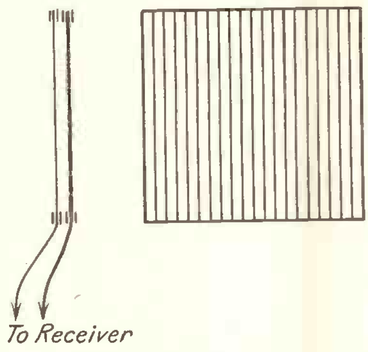


Fig. 13.—GENERAL ARRANGEMENT OF ELECTROSTATIC TYPE OF LOUD SPEAKER.

and the other end is free to vibrate. The vibrating end is driving the cone diaphragm.

The Inductor Loud Speaker

In the case of the inductor type the armature is so arranged that it moves like a piston in the magnet gap.

In comparing the three types of moving armature loud speaker, we can say that the balanced armature is an improvement on the reed type, and that the inductor type is an improvement on the balanced armature type.

In the case of the inductor type the armature has a considerable degree of freedom which can be compared with that obtainable in the cheaper types of the moving coil speakers. Provided that the loud speaker is properly designed and carefully assembled, the inductor arrangement will give the best frequency response

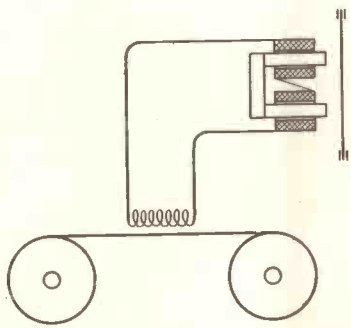


Fig. 15.—A DIAGRAM ILLUSTRATING THE REPRODUCTION OF SOUND BY THE BLATTNERPHONE METHOD.

characteristic than the other two types of moving armature.

The Moving Coil Loud Speaker

In the case of the moving coil loud speaker the moving armature is replaced by a delicate moving coil, as shown in Fig. 12. The moving coil is so suspended and so balanced that it is free to move horizontally in the space between the poles of the electro-magnet. The latter provides a strong unvariable magnetic field. The moving coil is connected to the output terminal of the receiver and therefore carries a varying current which causes a varying magnetic field around the delicately suspended coil.

The varying magnetic field causes repulsion and attraction to take place between the two fields, and since the moving coil is the only thing that can move, it vibrates and drives the light cone diaphragm.

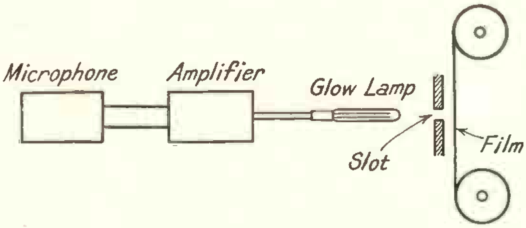


Fig. 16.—METHOD OF RECORDING EMPLOYED FOR TALKING PICTURES.

Importance of a Baffle

This type of loud speaker is the best type at present known, from the point of view of quality of reproduction. In order to obtain the best possible results from the moving coil loud speaker it is essential to use it in conjunction with a baffle. This will help to bring out at their proper value the lower frequencies, *i.e.*, the bass. Without the baffle air waves produced by the diaphragm are circulating from back to front and *vice versâ*, dissipating the energy produced by the loud speaker. For good bass response the baffle can be made up to 5 feet in diameter. If it is to be effective it must be made of *hard wood* not less than $\frac{7}{8}$ inch in thickness.

Box Baffles

The baffle itself should not be allowed to vibrate and should be therefore massive enough for this purpose. But who is going to install a big flat baffle, 5 feet in diameter, $\frac{7}{8}$ inch thick, rigidly built in? It would spoil the appearance of any room. For this reason the B.B.C. is recommending the so-called box baffle, which will do the same job but can be made much smaller. But such an arrangement is subject to booming. In order to cut out this boom the box is filled with slag wool. Such box baffles are now marketed under the name of "The Howe Box Baffle" (Pat. Applic. N. 378286) and can be had in kits from 20s. upwards.

It is interesting to note that Broadcasting House is equipped with moving coil loud speakers contained in box baffle cabinets, packed with slag wool.

Electrostatic Type of Loud Speaker

A couple of years ago another type of loud speaker made its appearance during the Wireless Exhibition. This is an electrostatic type, consisting of a corrugated metal plate with another flimsy metal plate suspended near it. An output choke has to be used with this loud speaker and apparently works on the principle of attraction and repulsion of electrified plates. It is claimed, as far as I remember, that the loud speaker is an advance on all the present types. I believe that a considerable output is required. The general arrangement is shown in Fig. 13.

Permanent Recording—The Blattnerphone Method

Now let us consider the methods of permanent recording. If we pass a steel tape rapidly between the pole pieces of an electro-magnet, the windings of which, like the windings of the telephones, are connected to the output terminals of either a receiver or a microphone amplifier, the varying magnetic field across the pole pieces will magnetise the rapidly moving steel strip with a varying intensity. If such a magnetised steel tape is now allowed to pass at the speed of recording near a coil of wire connected to a loud speaker-reproducing system, the varying magnetic field due to the steel tape will induce varying currents in the coil and the latter, after amplification, will cause a reproducing system to emit the recorded sounds. This is the rough outline of the Blattnerphone method used extensively by the B.B.C.

Aii prominent speeches are thus recorded, so that gradually a library of important records is being built for future reproductions.

As you see in this case, the magnetic field is being used once more, so that electrical energy is being transformed into a permanent magnetic record, and later this magnetic record is used for converting the magnetic variations into electric varying currents.

Recording for Talking Pictures

In " talkies " a different method is used. Here electrical currents are expressed as flashes of light, and the latter are photographed on a sensitive cinema film in the form of a sound track, beside the picture, this sound track consisting of a series of close lines of varying density.

The Method of Recording

The method of recording is shown in Fig. 16. A neon lamp is used for production of flashes, each flash depending on the strength of current passing through the lamp. The stronger the current the stronger the flash. As the modulated currents vary in intensity so the flashes will vary in luminosity, and this variation of illumination is being photographed from instant to instant on a rapidly moving film.

The Method of Reproduction

The method of reproduction consists merely in passing the film at the speed of recording before a strong source of light focussed upon the film with the help of lenses (Fig. 17). The light is focussed on the sound track of the film through a slot so that the only light that can emerge beyond this part of the film is that passing through the varying in density record of the variable luminosity of the neon lamp. In this manner the flashes of light filtered by the film correspond to the flashes of the neon lamp, and therefore also correspond to the currents which passed through the neon lamp. All that remains now is to re-convert the film filtered flashes of light into electrical currents again.

The Photo-Electric Cell

This is accomplished with the help of the so-called photo-electric cell. The latter is a device similar to a valve and possessing two electrodes, of which one is a source of electron emission and is made of substances rich in electrons, and the other akin to the anode of the valve. When the photo-electric cell is connected in circuit and left in darkness there is no current flowing from the cathode of the lamp to the anode, as in darkness the resistance of the inter-electrode space is infinite. Remember that there is no hot filament to emit the electrons. Now, as the intensity of light falling upon the photo-electric cell increases, the flow of electrons through the cell increases, and in this manner there is an electrical impulse through the cell for each flash of light. As you see, with the help of the photo-electric cell we can interpret light flashes in the form of electrical currents.

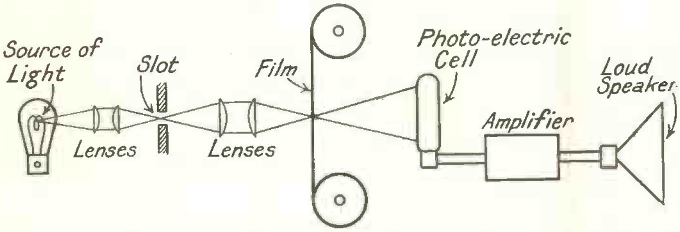


Fig. 17.—METHOD OF REPRODUCTION EMPLOYED FOR TALKING PICTURES.

Since the light flashes falling upon the photo-electric cell are those filtered by the film's sound track, and are, therefore, identical with the flashes produced by the neon lamp in the first place, the photo-electric lamp will develop currents identical with those that have been flowing through the neon lamp during the photographing process.

Having obtained these currents, all we have to do now is to amplify them and pass them on to a loud speaker.

This is, broadly, the method of recording and reproduction used by the "talkies."

Gramophone Recording

The last method of recording and reproduction we have to consider is that of the gramophone recording with the help of the electrical pick-up. The constructional details of this are shown in Fig. 18. An electrical pick-up consists of a permanent magnet system with a number of iron pole pieces carrying coils, not unlike a telephone receiver system. In the gap between the pole pieces is placed an iron armature carrying a needle. Now, if such a pick-up is connected to the output terminals of a microphone-amplifier circuit, the microphone currents will flow through the coils of the pick-up and will produce a varying magnetic field around the coils. This will cause the armature to vibrate sideways and the needle with it. Should such a pick-up be placed on a soft recording disc, being rotated in the usual way, the vibrating needle will cut a track in the record in the form of a groove varying in width.

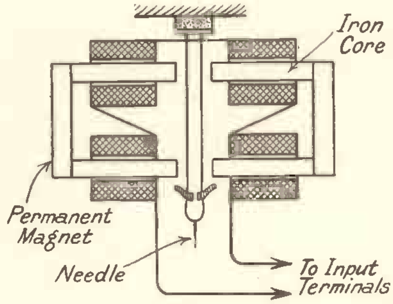


Fig. 18.—The Electrical Pick-up used for Gramophone Recording.

Microphone Currents

Thus, in this case, we start with microphone currents controlled by sound waves produced in front of the microphone. These currents are amplified and are brought to the windings of the pick-up. In the pick-up these electrical currents are interpreted in the form of a varying magnetic field, which controls the vibrations of the pick-up armature and the needle. The needle cuts a groove in the running record. It is thus quite clear that the microphone currents are being interpreted here in the form of a groove varying in width.

Reproduction from a Record

After we have recorded our sounds in this way, let us place the pick-up connected to a suitable amplifier and loud speaker on the record. As the record rotates, the needle, following in the cut groove, will follow all the vibrations of the cutting needle and will cause the armature, to which it is attached, to vibrate likewise. The armature in vibrating will change the magnetic field of the electromagnet and this change in the intensity of the magnetic field will cause a current to be induced in the windings of the pick-up. This current amplified and brought to the loud speaker will result from the latter in sounds which have been previously recorded.

It is thanks to the pick-up that we have electrical gramophone recording such as we know it to-day.

Now that my readers are more or less familiar with the manner of working of loud speakers, in the next article of this series we shall survey the whole cycle of events happening between the microphone and the loud speaker, with a complete analysis of the happenings in each part of the receiving circuit.

WIRELESS CONTROLLED MODELS

By EDWARD W. HOBBS, A.I.N.A.

THE possibilities of controlling models or machinery by wireless waves has exercised the minds of numerous inventors, and some remarkable results have been achieved, particularly the wireless control of crewless boats and various weapons of offence.

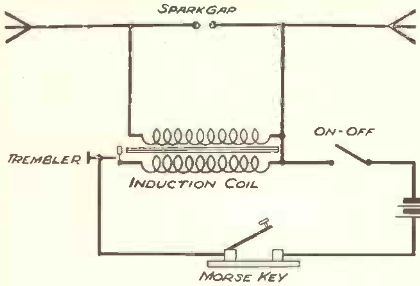


Fig. 1.—SPARK TRANSMITTER CIRCUIT.
Theoretical circuit of a simple spark transmitter used for distant control of models and machinery.

Transmitted Energy

There is relatively little difficulty in transmitting by wireless in such a way that a boat or a land vehicle or any kind of model can be controlled from a distance, provided the controlled object can be seen, and in this article a brief survey of some practicable methods will be given.

It must be pointed out, however, that a licence or permit must be obtained from the Postmaster-General to own and operate a transmitter, but a limited permit to use short-range apparatus not adapted for transmission of telegraphy or telephony can sometimes be obtained by a responsible experimenter engaged on serious work.

Transmitter and Receiver

A practical, simple and inexpensive short-range apparatus consists of a spark transmitter, consisting of the usual spark gap, induction coil, batteries and morse key, together with a small aerial and counterpoise earth, the circuit arranged as shown in Fig. 1, and *not* earthed as is usual.

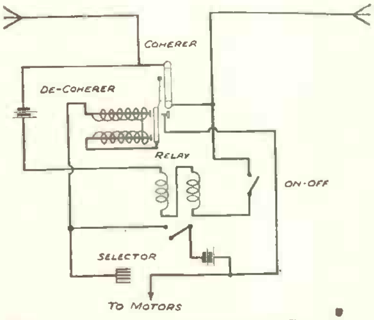


Fig. 2.—SIMPLE RECEIVER CIRCUIT.
This receiver, with coherer and relay, is used to pick up the spark signal and close a local circuit which by means of the selector actuates the model.

A simple receiver circuit is shown in Fig. 2, and consists of the coherer, decoherer, relay, selector, local battery and receiving aerial and counterpoise; but *not* earthed.

How the Circuits are Arranged

The circuits are so arranged that when the morse key is depressed and released, a spark jumps across the gaps and a pulse of electrical energy is radiated from the aerials. This energy is picked up by the receiving aerial passed on through the coherer to the relay, which then closes a local circuit. Although this method is now obsolete for commercial wireless work, it has the merits of simplicity and cheapness; moreover, it does practically all that an elaborate valve set can do to control a model.

Spark Transmitter

A good motor car ignition coil with "trembler" makes a practical induction coil, or a small "spark" coil can be used, as in Fig. 3, to which current should be supplied from a 4-volt accumulator controlled by a simple morse tapping key.

Aerial and Counterpoise

The aerial and counterpoise may be stout brass wires each about 24 to 48 inches long, clamped to wooden bases, and the

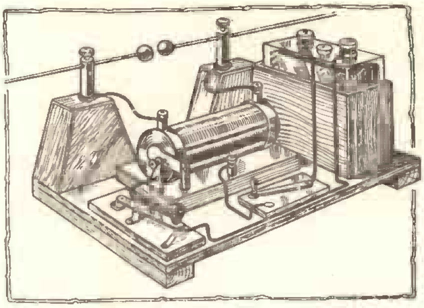


Fig. 3.—DETAILS OF TRANSMITTER.

The aerials have spark balls at the end and are supported in binding posts connected to the induction coil. The Morse key is in the front corner.

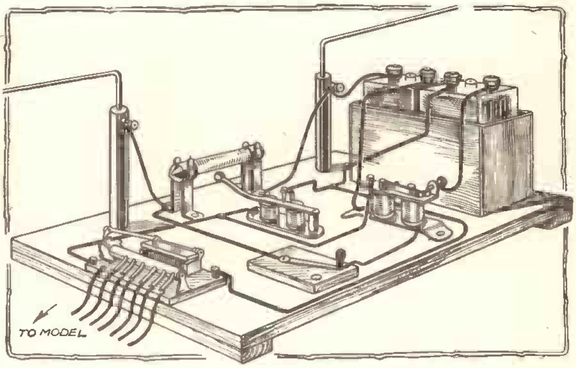


Fig. 4.—DETAILS OF RECEIVER.

The coherer is located between the two aerial wires; behind it is the de-coherer, with the relay to the right and the selector on the left.

whole arranged substantially as in Fig. 3—where the spark gap is clearly shown. The small balls should be about ½ inch diameter, always kept clean and bright, and the spark gap adjusted to about 1/16 inch between the balls.

All parts carrying high-tension current should be fully insulated with ebonite. A simple on-off switch and a fuse in the battery circuit are advantageous.

Details of Receiver

Essentials of a receiver adaptable for general use on a boat, or other model, comprise a receiving aerial and counterpoise each about 24 to 48 inches long, connected up, as shown in Figs. 2 and 4, to the coherer. One form of coherer consists of a glass tube about 4 inches long, with contact plugs in each end. The space between is loosely filled with clean dry brass filings, or preferably with 90 per cent. nickel and 10 per cent. silver filings. When such a device is inserted in a circuit including a low-voltage battery, the resistance of the loose filings is so high that practically no current flows, but a high-frequency current causes the filings to "cohere" or cling together, the resistance drops to a few ohms, and allows the local current to flow freely.

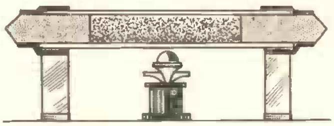


Fig. 5.—COHERER AND DE-COHERER.

Sectional diagram showing the coherer with metal contact ends and metallic filings loosely filling the glass tube. The hammer of the de-coherer is beneath the tube.

The De-coherer

To separate the filings after the current has passed, it is necessary to "tap" or agitate the filings, which can conveniently be done with a miniature buzzer or electric bell mechanism so arranged—as shown diagrammatically in Fig. 5—that the vibrating hammer strikes the coherer and shakes up the filings.

The de-coherer is in the local battery circuit, which is closed by the relay. A simple relay for normal use must be *sensitive and reliable*, with a resistance of

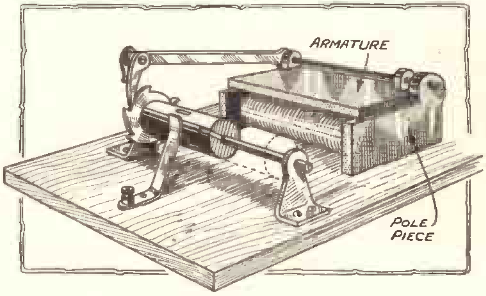


Fig. 6.—SEQUENCE CONTROLLER.

When the electro-magnet is energised it attracts the armature; the arm thereon engages the ratchet wheel on the contact drum and moves it through a partial revolution, thus bringing a different circuit into action. Only one contact arm is shown, but any number can be used.

about 100 ohms, but need not be of the "polarized" variety.

Sequence Controller

Having arranged the transmitter and receiver so that impulses can be propagated between them and the relay thereby actuated, it is necessary to devise the local circuits and devices that actually control the boat or other object.

One of the simplest and most convenient of these devices is the sequence controller—shown in Fig. 6—which consists of an electro-magnet with a ratchet arrangement so devised that each time an impulse is received the ratchet is depressed and a contact drum rotated through about 30 degrees.

Five or more contact brushes bear against the drum, so that one only makes contact at a time with a contact on the drum. It is in effect an automatic single-pole 5-way switch which closes any one of 5 circuits.

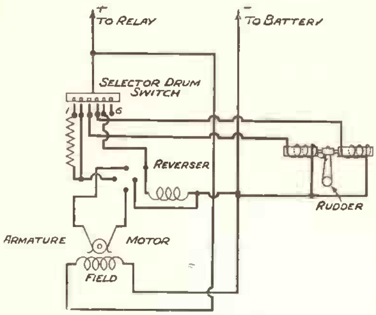


Fig. 7.—SEQUENCE CIRCUIT.

This diagram shows how various devices are brought into or out of circuit by the movement of the contact drum on the selector.

Local Circuits

One example of how such a sequence controller can be applied is shown in Fig. 7—which is adaptable to a model boat of reasonable dimensions, say 5 to 6 feet long, 12-inch beam and 6-inch draught, with a displacement of 70 to 80 lb.

The boat is started on its course by turning the sequence controller to No. 1, which starts up the motor at slow speed ahead. The next impulse moves the controller forward one space, to No. 2, which increases the motor speed to full speed ahead. The next impulse advances the controller again by one space, to No. 3, which moves the rudder and turns the boat to port (to the left); the fourth impulse brings No. 4 into circuit, and turns the boat to starboard (to the right); the fifth impulse brings No. 5 into circuit, reverses the motor, and runs the boat backwards. No. 6 is, of course, "off," that is, the boat will come to a stop, but it is possible by a slight alteration to the circuit to so arrange matters that the boat will continue indefinitely on whatever course it may be set, until a fresh impulse is received, no current flowing meanwhile through the local circuits.

Delay Action Control

One further refinement is desirable, and that is, a delay action device of some kind, such as the "Bulgin" Thermal delayed-action switch. This incorporates a heater winding, so arranged that when current flows through it a bi-metal strip overcomes the pressure of a spring and it "clicks" over, thus closing a main circuit. Inserting this device in the circuit as in Fig. 8, delays the flow of current for a few seconds, hence it is possible by rapidly operating the morse key to bring any desired sequence contact into position before the main current actually flows, hence the boat responds easily and without jerkiness to the transmitted signal.

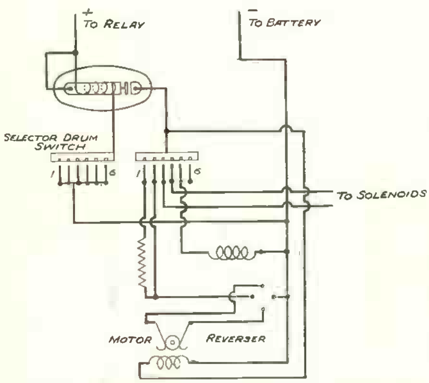


Fig. 8.—SEQUENCE CIRCUIT WITH DELAY-ACTION SWITCH.

The delay-action switch is placed in the feed wire from the local battery. The heater circuit is closed when a contact is made with the drum switch; duplicate contacts close the main circuit through the heater.

A model railway or almost any kind of mechanical device can be controlled effectively in a similar manner, such operations as moving the rudder, raising or lowering a signal, or opening and closing a door, or switching lights on or off, being effected by a simple electro-magnet or solenoid, as in Fig. 9, and a lever arm and linkage system.

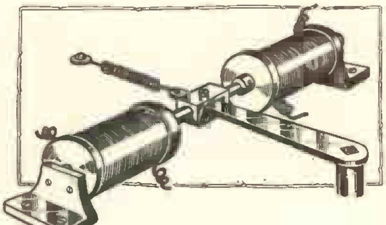


Fig. 9.—Solenoid Device.

Two solenoids are arranged in tandem. When either is energised it pulls the lever towards the energised solenoid. The lever can move a rudder, open or close a switch, move a door or other part of the model or machine.

Valve Apparatus

A valve transmitter may be generally similar to an oscillator wavemeter, and the receiver an ordinary single valve set tuned to the same frequency. The coherer is not used, and the relay is inserted in the anode circuit and delicately adjusted so that it responds only when the anode current flow increases when the incoming signal is received. By substituting a suitable microphone in the transmitter in place of the morse key, the model can be controlled by a decisive word of command, the speech vibrations in the microphone being transmitted as usual and actuating the receiver in the same way as if the morse key had been tapped.

Numerous and intricate mechanisms have been devised, but most of them are for specialist purposes, and not of general application. In recent years attention has been directed more to the adaptation of the photo-electric cell or "electric eye," and the use of white or coloured light rays, and predetermined arrangements of signal pulses, using a device akin to the "Auto-Alarm" as used on ships.

WORKING A MODEL TORPEDO BOAT DESTROYER BY WIRELESS CONTROL

A Specific Example

A concrete example of the application of wireless control to a model is that of a working model torpedo boat destroyer.

Dimensions of the hull are 6 feet long, $7\frac{3}{4}$ inches beam, 6 inches depth, total weight, 38 lbs. Motive power, steam, supplied from a centre flue boiler fired by a

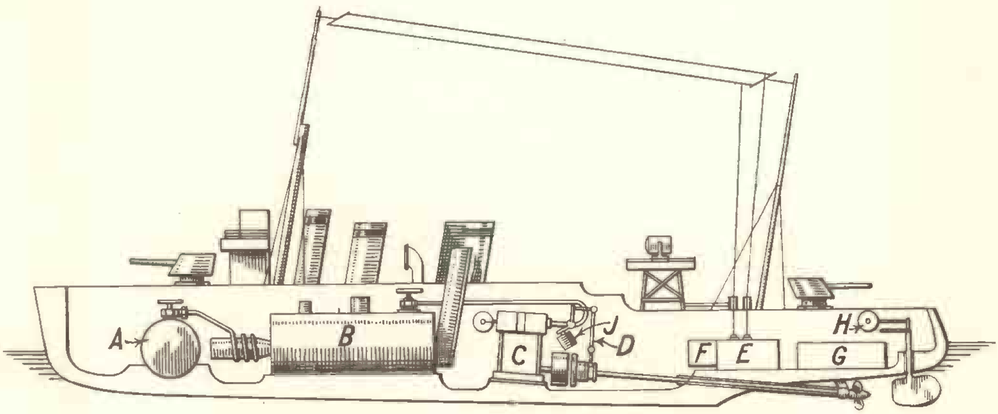


Fig. 10.—Schematic Arrangement of Parts.

Here are shown the boiler, engines and wireless and electrica devices for control of a model boat from a distance. A is the blowlamp; B, boiler; C, engine; D, magnetic clutch; E, receiver; F, selector; G, batteries; H, steering solenoids; J, steam control solenoid.

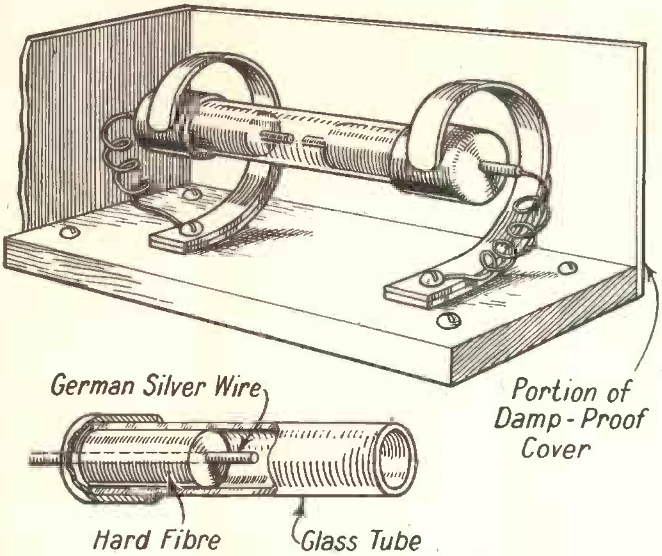


Fig. 11.—IMPROVED COHERER.

The coherer is mounted on C springs, and the vibration, when struck by the decoherer hammer helps to ensure perfect decohering.

petrol blowlamp, and steaming a twin-cylinder double-action reversing engine. The general scheme is shown in Fig. 10.

Practical Difficulties

One unexpected trouble was that the engine would not always start up when the steam was turned on; this was a mechanical trouble, mostly due to condensation in the valve parts and *not* any fault of the wireless control. To overcome this trouble a magnetic clutch was fitted; this allowed the engine to run constantly except when "reversed."

Reversing did not present any trouble, as the engine was hot and "dry"—that is, free from condensation.

Dual Safety Valves

No attempt was made to reduce the burner pressure when steaming slowly or when "stopped"; instead reliance was placed on a pair of very efficient "Pop" safety valves in place of the one normally fitted; in practice this worked quite well.

The magnetic clutch was interconnected with the steam throttle valve and so arranged that when the clutch was released it nearly closed the throttle, thus keeping the engine at a reasonably low speed.

Counterbalances

Owing to the perceptible friction and load on the clutch gear, throttle and other controls subject to steam pressures, all controls were counter-weighted as far as practicable, so that they called for the minimum of electrical energy to operate.

Spring-loaded Controls

One difficulty common to many electrically controlled devices is that a solenoid or similar device acts with sudden violence, and is limited in its length of movement. To avoid too violent shocks on the mechanical controls a system of spring-loaded controls was evolved, of which details are given later.

Having thus arranged the mechanical parts in a manner favourable for electrical

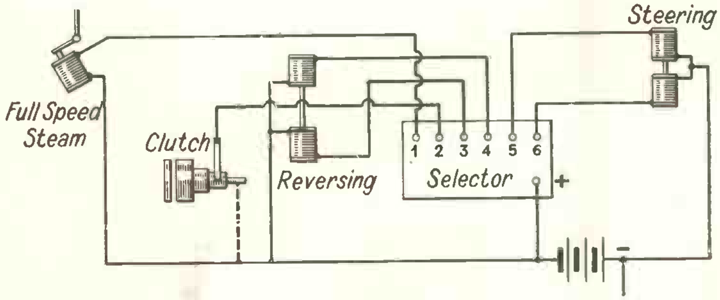


Fig. 12.—CIRCUIT DIAGRAM.

Outline circuit showing main leads to the various solenoids and magnets from the selector. The delay action and other leads are as shown in previous diagrams.

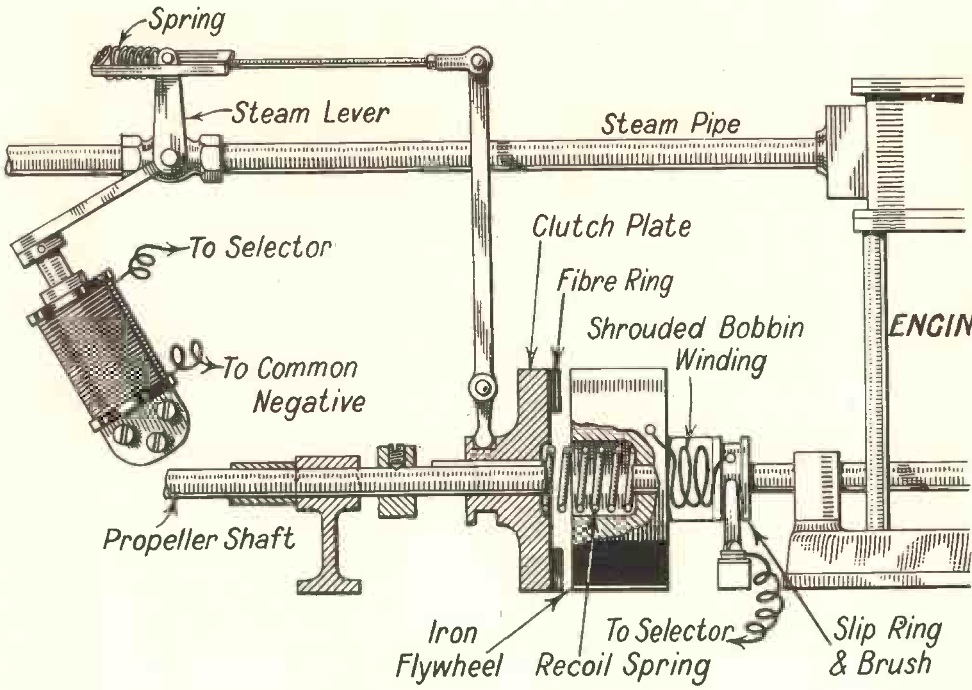


Fig. 13.—DETAILS OF MAGNETIC CLUTCH.

The magnet on the engine shaft, when energised, attracts a movable clutch member on the propeller shaft. The long lever connects to the main steam valve.

control and manipulation, some consideration can now be given to the wireless and electrical installation.

Transmitter and Receiver

The transmitter and receiver were substantially similar in design to those already described, but the receiving aerial was slung on yards hoisted on two tall masts on the boat, the transmitting aerials were supported by light rods about 8 feet long set up in the earth and supported by light guy wires separately insulated.

Transmissions were made with a tapping key as usual—and reception through a coherer and sequence controller.

Coherer Failures

Troubles with the coherer were frequent at first, but the type shown in Fig. 11 proved quite reliable when kept dry—not an easy thing to ensure on a model boat in a rough sea. A cardboard cover, painted inside and out with shellac varnish, proved effective as a protection against spray, steam, etc., and removed this source of trouble. It is shown clearly in section in Fig. 11 showing the coherer.

Improved Coherer

Most of the troubles with the coherer are due to persistent cohesion, or a reluctance by the metallic filings to shake up and restore the resistance.

These difficulties were overcome by using a small size coherer with nickel, 80 per cent., and silver, 20 per cent., perfectly clean filings. These were loaded loosely into a glass tube, $\frac{5}{16}$ inch bore, 1 inch long, each end of the tube closed by a metal cap having an internal wire extending nearly to the centre of the tube, leaving a gap of about $\frac{3}{32}$ inch between them. A hard fibre bush is fitted over each wire, as shown in the inset in Fig. 11.

German silver wire was generally used, about No. 26 S.W.G., and the whole so arranged that each wire projected about $\frac{1}{16}$ inch beyond the fibre bushes.

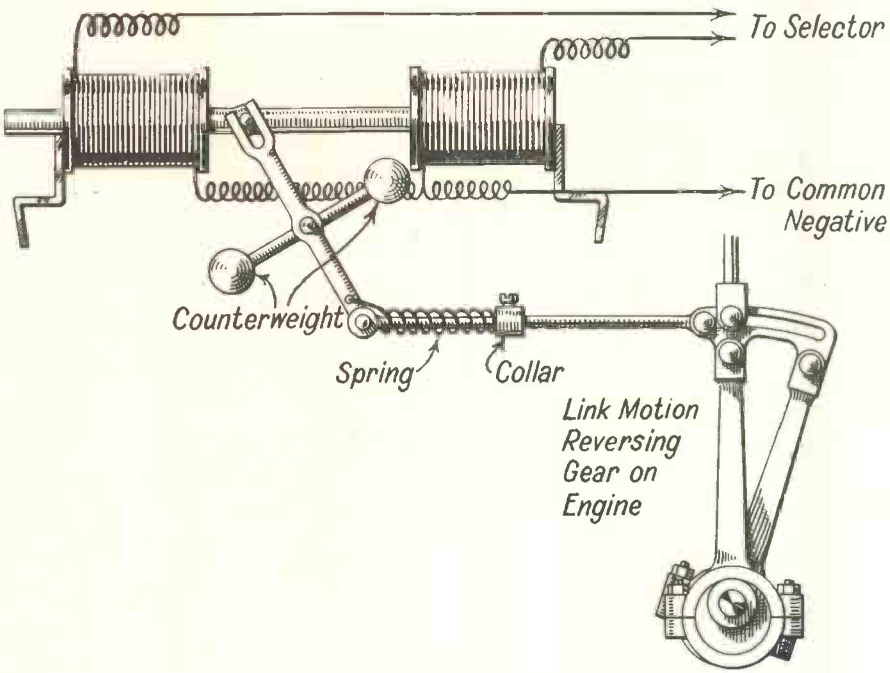


Fig. 14.—REVERSING SOLENOID.

This is a double-action control, one solenoid pulls valve gear to "ahead" position, the other solenoid moves it to "astern" position. Note the use of counterweights and spring shock absorber.

The wires are brought out near to one side of the glass tube, and this part of the tube is called the front.

The tube is mounted on thin, hard brass spring supports with a secondary or backing spring behind each, as shown in Fig. 11. The coherer caps are soldered to the springs, and a soft, flexible wire connected between a contact screw on the spring and the projecting wire end, and the whole mounted on an ebonite base.

Vibrating Supports

Arranged in this way, the coherer vibrates at a certain frequency when struck by the broad face of the de-coherer hammer; moreover, as

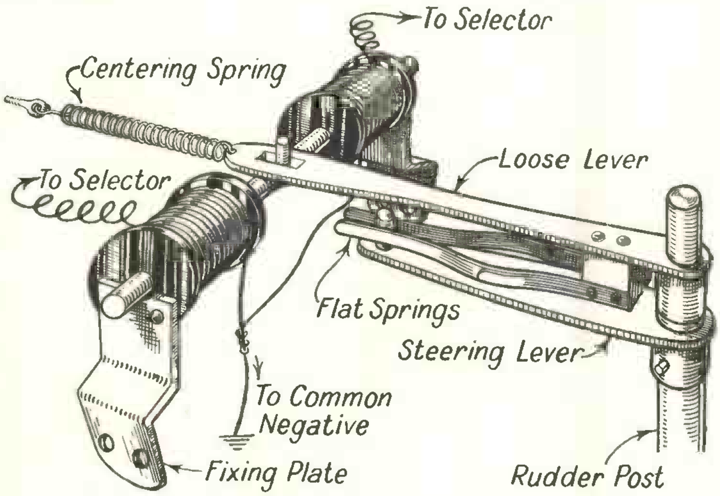


Fig. 15.—STEERING SOLENOID.

Double-action solenoid, one impulse moves lever to right, the next moves it to the left; when current is not on the lever comes to central position by spring action.

the frequency of vibrations of the hammer and the coherer do not synchronise, there are a succession of regular taps and a few sharp " peak " taps.

Furthermore, the direction of the hammer blows are such that the filings are forced away from the contact wires—a further aid to reliable de-cohering.

Scheme of Operations

The scheme of operations of the device as installed allowed for steering, reversing, stop and start, slow and top speed. To do this necessitated a six-way selector, the skeleton diagram of which is shown diagrammatically in Fig. 12, the selector itself being as already described, but housed in a damp-proof covering.

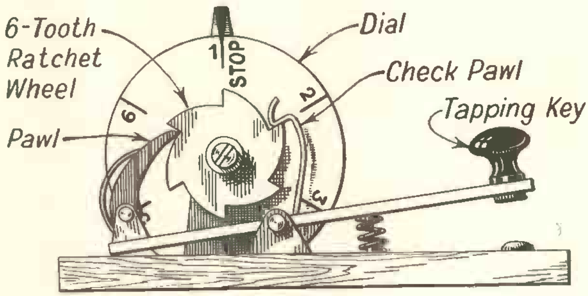


Fig. 16.—Transmitting Indicator.

This device enables the operator to know which control is in use at any time.

The stop and start device consists of an interconnected magnetic clutch and steam throttle valve.

The clutch, shown in Fig. 13, consists of a bobbin winding on the engine shaft, one end earthed to the frame, the other taken to a slip ring and brush. Current can flow through this winding under normal conditions and thereby energises the magnet and attracts a slidable iron disk with fibre friction ring attached to the propeller shaft.

When the sequence controller is brought to the " off " position it breaks this magnet circuit, and the phosphor bronze release spring forces the movable member backwards, and at the same time moves the lever and link system, which turns the steam nearly off. The boat stops because the propeller is not revolving, but the engine just keeps running.

Steam Throttle Valve

When the engine is running and the clutch engaged, the lever system aforementioned turns steam to half speed, but when full speed is required a solenoid is energised by means of the selector closing a contact and the action of the solenoid draws the steam lever further over to the full speed position.

A link and spring on the clutch arm is compressed by this action, so that when half speed is required, the current to " throttle " solenoid is cut off and the spring returns the steam valve to the half speed position.

Reversing System

Ordinary Stephenson link motion reversing gear is fitted to the engine, and this is operated by a double solenoid motor on the lines shown in Fig. 14; here again a buffer spring is interposed between the solenoid lever and the reversing lever to reduce the sudden shock when the solenoid is energised, and also to ensure that the reversing lever is forced right home. The spring is a tension spring anchored to a collar at one end and to the solenoid lever at the other end; in this way it operates in either direction.

Rudder Gear

A similar double solenoid motor is used to control the rudder, but in practice it was found that the shock of the sudden action of the sharp pull of the solenoid was liable to cause the rudder blade to rebound and upset the control.

To obviate this a dual lever system was devised, as shown in Fig. 15; one lever is fixed to the rudder post, the other lever is free to turn upon the rudder post.

The two levers are connected together by a tension spring.

It should be appreciated that by careful adjustment of the delay action switch, already referred to, it is possible to run very quickly through the whole six sequence transmissions and to come back to any desired position without seriously disturbing the control of the boat.

GRAMOPHONE PICK-UPS

By W. GEORGE

Fig. 1.—Details of a B.T.-H. Senior Pick-up.

The rubber damper is the round rubber rod held in position by the holder at " A." The pick-up is removable from the arm, contact being made to the leads by the contact spring " B."

Modern Reproducing Mediums

THE pick-ups available to-day are not by any means the last word, but with the benefit of four or five years' experience of design and manufacture behind them nearly all the reasonably-priced models can be relied upon to provide a satisfactory performance.

The various illustrations given show the external appearance of quite a number of these, and it will be noticed that these are complete with their own carrier arms, the arms varying in shape according to the type of pick-up adopted, to ensure the smallest possible error in tracking, taking into consideration the length of these carriers.

Ideal Tracking

To enable ideal tracking to be obtained, the arm would have to be of considerable length, so that the arc produced by the needle when the pick-up and arm is moved round on its supporting pillar, across the playing surface of a 12-inch record, is as near as possible to a straight line ; this, of course, is inconvenient in practice, and consequently a suitable compromise must be effected.

Importance of Bearings or Swivel Joints

All the good qualities of a pick-up can be offset if bearings or swivel joints are too tight or too loose, resonances are produced, record wear will probably be abnormally high, and quality in all probability will suffer.

Bearings Too Tight

Where tightness of bearings is encountered the record will have more work to do by pulling the needle into each successive groove instead of this gliding in freely without friction, consequently record wear will be considerable and the correct weight will not be on the needle point, resulting in poor reproduction.

Fig. 2.—The B.T.-H. Senior de Luxe Pick-up.

This model is finished in antique bronze; details of the pick-up are as follows:

Impedance at 4,500 cycles, 40,000 ohms.

Average output, 1 volt R.M.S.

Recommended volume control, 20,000 ohms.

Recommended needles, medium or loud tone.

Bearings too Loose

In the case of looseness, apart from bad resonances which we wish to avoid, the needle most probably will tend to lay over one side, which again will spoil our records. Special attention is paid to these important points by manufacturers, and all the models described herein are excellent in this respect; the main pillar bearing is invariably of the ball-bearing type.

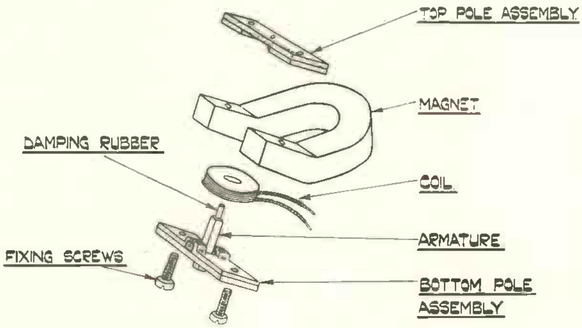


Fig. 3.—Details of the Construction of the Magnet System of the B.T.-H. Pick-up.

Carrier Arms

Carrier arms are mostly of stout construction to ensure rigidity, and the weight of these, combined with that of the pick-up head, would place too great a strain on the needle point if this was not counteracted in some way; in the case of the Marconiphone accessory a counter-balancing weight is used, and with most other types a spring-loading arrangement is adopted.

Output

On referring to the curves shown it will be seen that these do not differ widely, and it would seem, therefore, that it is mostly a matter of output, finish and cost which has to be studied in selecting a suitable model. When a pick-up is to be used with an existing receiver or amplifier and there are three stages of amplification, including in the case of the first mentioned, the detector, an average output of ½-volt or a little below this is sufficient; with two stages of amplification an output of about 1 volt is suitable. This is only generalising, of course, as it naturally depends on the stage gain, that is, whether the valves are resistance or transformer-coupled, and other factors, but manufacturers, without exception, supply suitable operating data in this direction.

Points About the Curves

To refer once again to the manufacturers' curves, it might appear that the

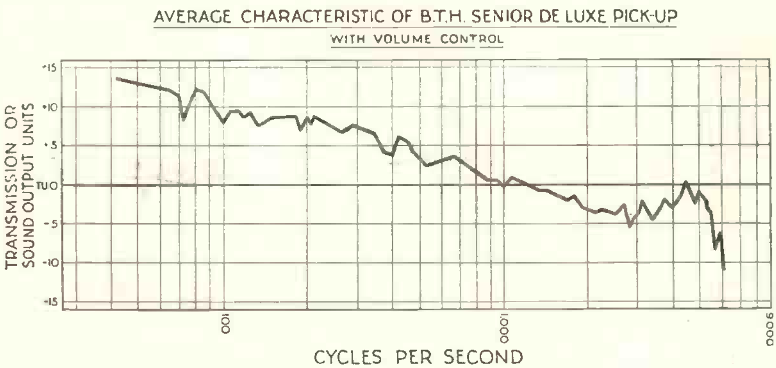


Fig. 4.—Average Characteristic Curve of B.T.-H. Senior de Luxe Pick-up.

number of small peaks which can be seen might have some detrimental effect on quality of reproduction, but aurally these do not exist, and it is only the slightly larger peak which occurs at 4,000 or 5,000 cycles which has any real value. This part of the scale helps considerably to add brilliancy to the reproduction, and, therefore, to a great extent it proves to be an asset. All the curves slope upwards at the low - frequency or bass end of the scale, and, this is desirable to overcome recording drawbacks, allowing reproduction to be well balanced, which is very desirable.

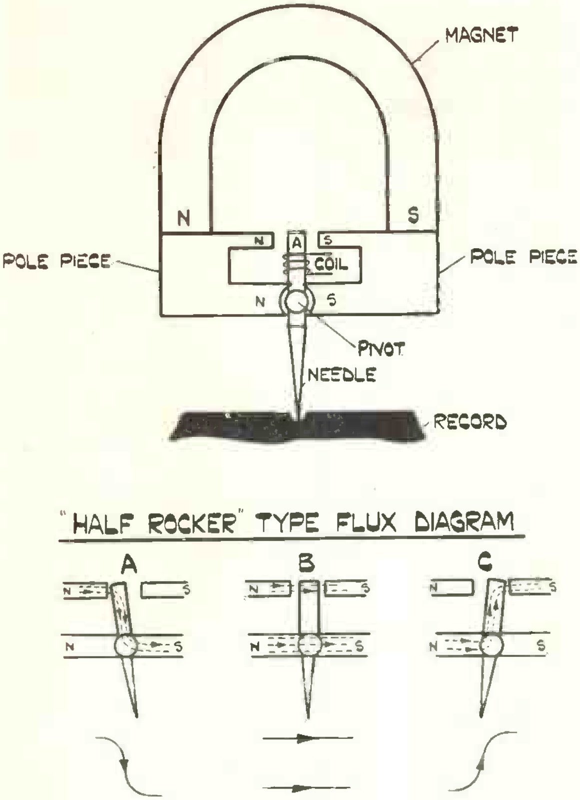


Fig. 5.—PRINCIPLE OF THE "HALF-ROCKER" TYPE B.T.-H. PICK-UP.

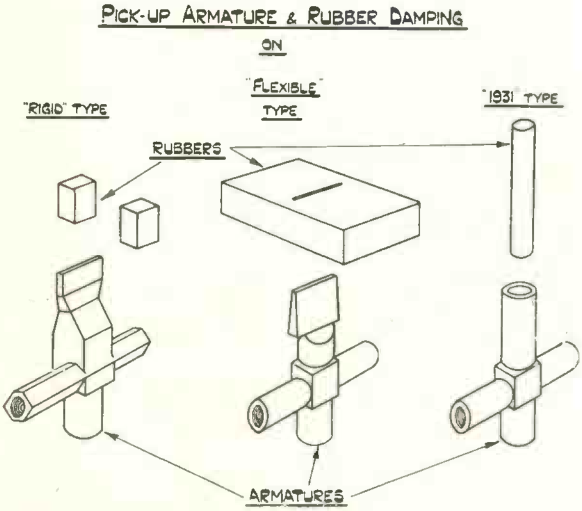


Fig. 6.—B.T.-H. ARMATURE AND DAMPING ELEMENTS. Showing stages in their evolution.

PICK-UP INSTALLATION AND THE REDUCTION OF SURFACE NOISE

The first job when installing a pick-up is the fixing of the combined pick-up and carrier arm to the motor board, and once having decided on round about the spot where this should be carried out, this piece of work should not prove too difficult.

Use the Manufacturers' Template

Manufacturers supply suitable instructions or templates to ensure that this shall be fitted in the correct spot in relationship to the turntable spindle, and, realising the importance of this matter, this is usually dealt with fairly comprehensively; a little extra time spent in making a good job of this part of the business will be paid for by less record wear.

Correct Needle Angle

Before fixing down the carrier arm there is another important point which must be borne in mind and that is the necessity for keeping the correct needle angle as provided by the manufacturers,

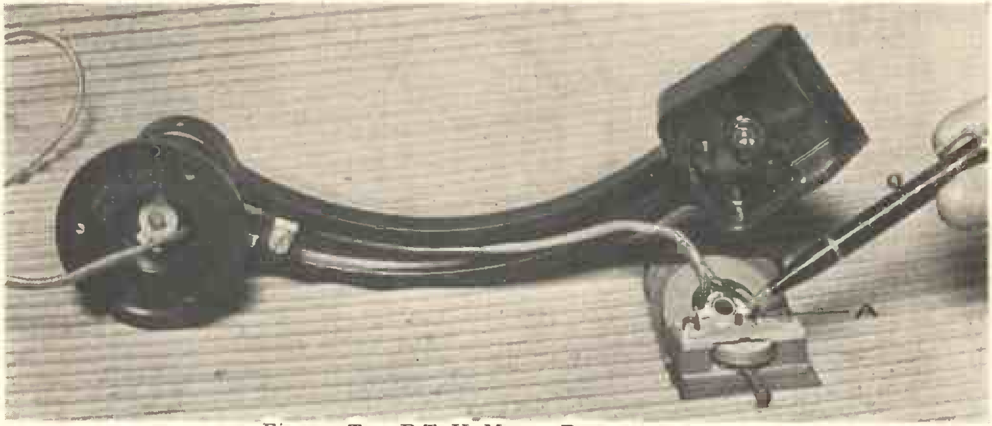


Fig. 7.—The B.T.-H. Minor Pick-up.

The rubber damper "A" is held in the cross member and is not adjustable. The pick-up is removed from the case by unscrewing the centre screw. Details of the pick-up are as follows :—

Impedance at 4,500 cycles, 29,000 ohms.
Average output, 0·5 volt R.M.S.
Recommended volume control, 10,000 ohms (fitted).
Recommended needles, medium or loud tone.

as it is obvious that this will vary according to the height of the turntable from the motor board.

When Packing Should be Added

Where the fulcrum of the arm is at the top of the supporting pillar, it is wise to add packing of a suitable material to the base of the pillar so that the arm when in the playing position is as nearly parallel to the motor board as possible. In the case of such pick-ups as the Varley " Mass Suspension " and the B.T.H. " Senior de Luxe," where the head itself is hinged to the carrier arm, the maker's instructions with regard to the height of arm above the turntable should be carefully followed.

Messrs. Varley supply with their instruments a set of black fibre washers, suitably drilled to enable them to be set at the correct height.

Earth the Carrier Arm Pillar

It is advisable to earth the carrier arm pillar, where this of metal, together with the arm and pick-up head casing, making it impossible for stray fields, where an electric gramophone motor is employed, to cause trouble.

The Volume Control Potentiometer

When a volume control potentiometer is necessary it is generally possible, by judicious positioning, to keep the pick-up leads quite short, this being a distinct advantage in avoiding hum and other troubles, especially where an abnormally high impedance

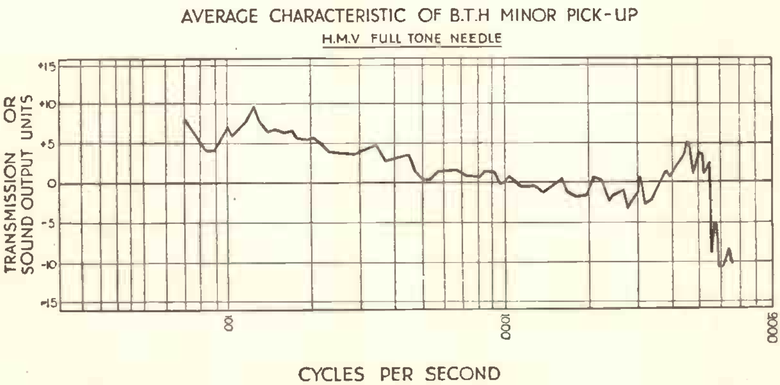


Fig. 8.—Average Characteristic Curve of B.T.-H. Minor Pick-up.

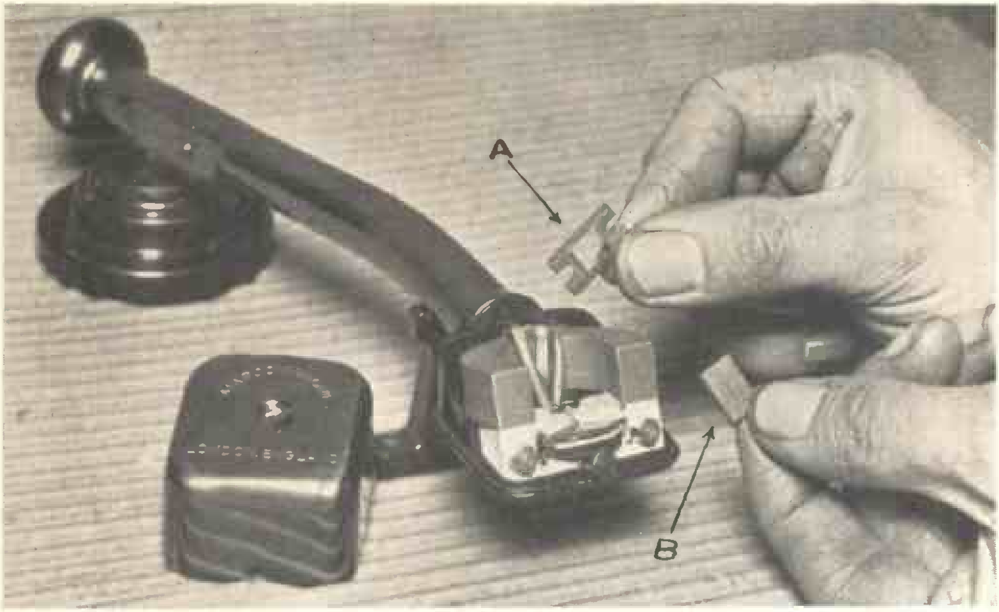


Fig. 9.—THE MARCONIPHONE PICK-UP, TYPE 17.

The rubber damper "B" has a slit which engages in the pick-up of the armature. This damper is held in position by the metal holder "A", which must be adjusted so that the armature is in the centre. Details of the pick-up are as follows :—

D.C. resistance, 6,000 ohms.
Impedance at 800 cycles, 37,000 ohms.
Average output, 1 volt R.M.S.
Volume control recommended, 250,000 ohms.
Recommended needles, Tungstyle.

instrument is used. It may be necessary in any case to use shielded leads, with the shielding earthed to ensure freedom from hum, etc., but where leads are a few feet in length, low capacity screened cable is definitely to be recommended.

Fixed Resistance Across the Pick-up Leads

In a great many modern receivers a suitable gramophone volume control is already incorporated, this being ganged with the radio volume control, and where this is in existence an external control is unnecessary; a fixed resistance of the metallised variety might be desirable, connected across the pick-up leads, according to the type of accessory in use, to enable the required tone quality to be obtained. Apart from this it is merely necessary to make connection to the sockets usually provided. The resistance can have a value of 25,000 or 50,000 ohms, and sometimes as low as 10,000 ohms, but conditions differ widely, and experiments should be made to determine the best value. Most probably a fairly low value will be required to obtain something like a correct balance in reproduction where an uncorrected pentode output valve is used following a very selective receiver.

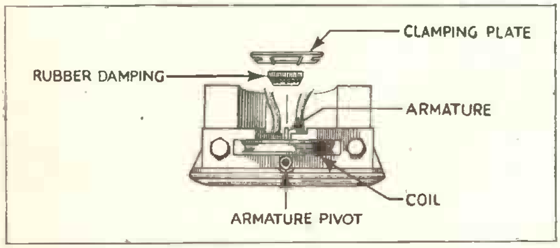


Fig. 10.—DETAILS OF THE MARCONIPHONE TYPE 17 PICK-UP.

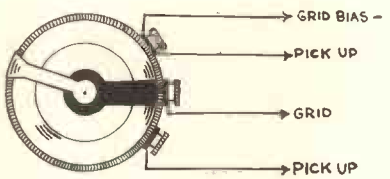


Fig. 11.—How to connect a Volume Control to a Pick-up.

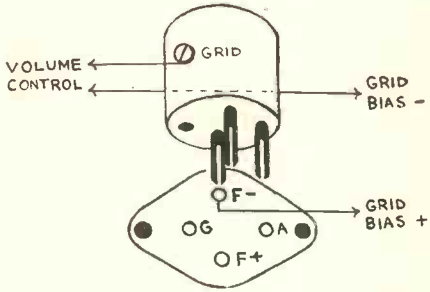


Fig. 12.—This shows how the Grid Circuit is Broken.

Type of Volume Control to Use

If a volume control has to be purchased, this should be of the potentiometer type and of the value recommended by the manufacturers of the pick-up, to ensure the best results ; a shunt resistance or scratch filter can be added later if desired. The volume control should be connected to the pick-up, as shown in Fig. 11, the pick-up leads going to the outer terminals of the potentiometer, one of these terminals being taken also to earth or grid bias, according to the type of receiver or amplifier, and the centre terminal to the grid of the first amplifying valve.

Connecting a Pick-up to an Existing Receiver

It would perhaps be as well before going any further if we dealt fully with the matter of connections to an existing receiver where pick-up terminals are not fitted ; this situation is usually confined to battery-operated receivers, but the same arrangement can be adopted in the case of instruments designed to work off A.C. mains, if it is not desired to make any alterations to the receiver.

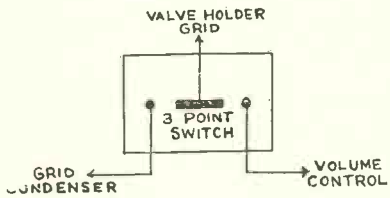


Fig. 13.—Showing the Use of a Three-point Two Position Switch.

How the Grid Circuit is Broken

It is usually the detector valve which is adopted as the first amplifying valve. The valve should be withdrawn and an adaptor inserted in its socket, this having three pins in the case of a battery valve and four where it is of the mains type, the valve being replaced in the top of this. As will be seen in Fig. 12, this allows the valve to be fed with the usual H.T. and L.T., but the grid circuit is broken, thus putting the H.F. part of the receiver out of action, which prevents any break through of radio when gramophone reproduction is taking place.

The lead from the centre terminal of the volume control is taken to the grid of the valve, and therefore this should be connected to the appropriate terminal on the adaptor ; the second wire should be connected to a suitable value of negative grid bias as shown, this being $1\frac{1}{2}$ or 3 volts, usually the former.

Drawback to Use of Adaptor

The only drawback with the use

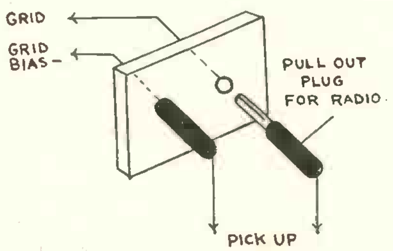


Fig. 14.—Alternative Arrangement to that shown in Fig. 13.

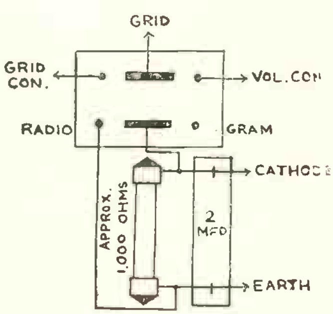


Fig. 15.—Connections for Introducing Automatic Grid Bias in an A.C. Mains Receiver.

of an adaptor is that this must be withdrawn from the circuit when it is desired to listen to radio.

There is an alternative, however, to make a more or less permanent job. A three-point two position switch can be fitted to the receiver which will obviate the necessity of disconnecting the pick-up lead from the grid terminal or pulling out a plug each time to enable radio reception to be obtained. The connections are shown in Fig. 13, where a switch can be fitted and where this is not possible the arrangement in Fig. 14 should be adopted, making a disconnection for radio as mentioned above; in this case the radio set should be detuned or the radio volume control put to the "off" position.

The Grid Lead

If the grid lead in the receiver must be more than a few inches in length, low capacity shielded cable, with the shielding earthed, should be used. It is not advisable to try to introduce automatic bias in the case of an A.C. mains receiver unless the radiogram switch, which must then be of the two-pole three-point variety, can be fitted near the detector valve; connections should be made and a resistance and fixed condenser used of the values as shown in Fig. 15.

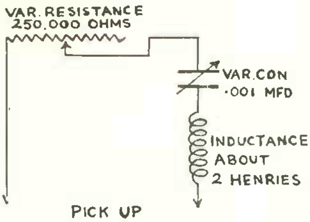


Fig. 17.—ARRANGEMENT FOR ELIMINATING SCRATCH AND SURFACE NOISE.

Using a Potential Divider

There are, of course, several methods in addition to the use of a potentiometer, as shown, of controlling volume. These necessitate the use of a form of potential divider across the pick-up if there is any possibility of the first amplifier valve becoming overloaded, so that only part of the generated voltage is used. The value of this divider should be the same as recommended by the makers of the pick-up for the volume control in the ordinary way, and the two sections should be so proportioned that the requisite output is obtained; Fig. 16 shows how the connections should be arranged.

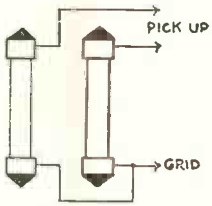


Fig. 16. — CONNECTIONS FOR USING A FORM OF POTENTIAL DIVIDER.

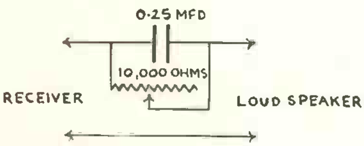


Fig. 18.—ARRANGEMENT FOR PROVIDING BASS CUT-OFF.

A Word on Scratch Filters

There are several schools of thought in the matter of "needle scratch," some reasoning that this is confined to a certain narrow band of frequencies, and others that it comes in to a greater or lesser degree on the various peaks in the characteristic of the pick-up. Where an ordinary normal degree of amplification is concerned we can safely assume that the scratch is a product of the peak in the curve which occurs at round about 4,000 or 5,000 cycles, and with this in our minds we can prepare to lessen the size of this with the object of giving us a little cleaner background in the reproduction.

How Scratch and Surface Noise can be Removed

We have seen that a resistance connected across the pick-up leads can affect the tone of the reproduction, there being more cut off at the top end of the scale as the resistance is lowered, and if this is continued we shall eventually get rid of the peak referred to above. Scratch and surface noise will not be reduced materially until this peak is removed, but with the removing of it in this manner the reproduction will lack brilliance and become lifeless. There is not too much top register on a record in the ordinary way, but what there is there is sufficient to allow us to obtain

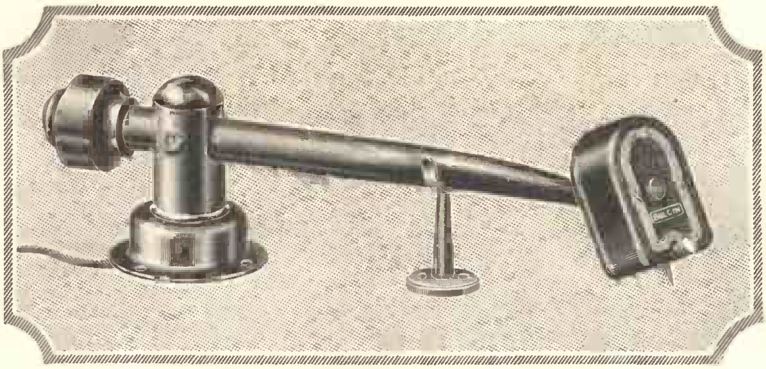


Fig. 19.—The Bulgin Pick-up.

Details are as follows :—
Average output, 0·4 volt R.M.S.
Volume control recommended. Not to exceed 75,000 ohms.
Needles recommended, loud or medium tone.

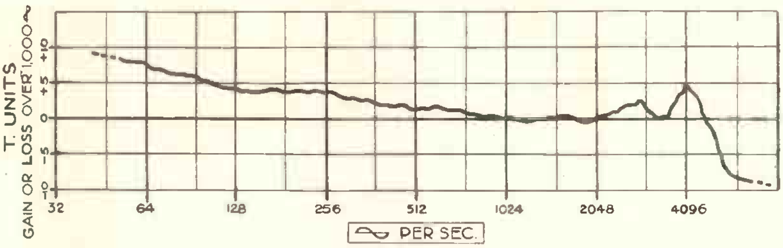


Fig. 20.—Average Characteristic Curve of Bulgin Pick-up.

realistic reproduction, and we want, therefore, to retain as much as possible.

The use of a capacity round about ·006 mfd. in series with an inductance of somewhere near ·2 henry (it is difficult to give any definite figures owing to varying characteristics) usually enables some relief from surface noise to be obtained, when wired in shunt with the pick-up. This usually leaves a trough in the curve, however, and, as this is to be avoided, resistance should be added to the circuit, as shown in Fig. 17.

Fig. 21.—The Harlie Pick-up Model 36.
D.C. Resistance, 2,500 ohms.; Average output, 0·8 volt R.M.S.; Volume control, 50,000 ohms.

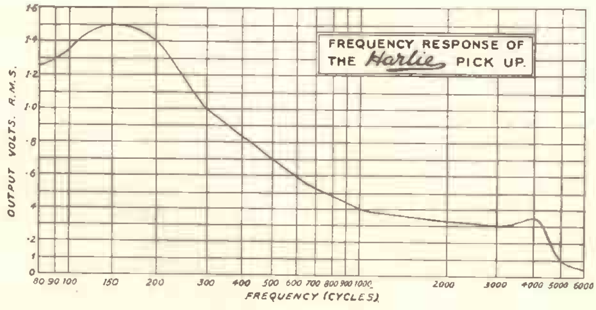


Fig. 22.—Average Characteristic Curve of Harlie Pick-up.

Quite good results should be obtained with this arrangement when suitable adjustments have been made to the resistance and condenser.

Tone Control

Where a "Pentode" valve is used in the output stage our task in this direction is made more simple, as we are able to use a simple corrector in the anode circuit consisting of a variable resistance of about 20,000 ohms in series with a fixed condenser of ·01 mfd. There is one exception, however, where this arrangement is not desirable; where the pentode valve follows a very selective receiver, because, although it is necessary to get a good balance in gramophone reproduction, the balance would be upset in the case of radio.

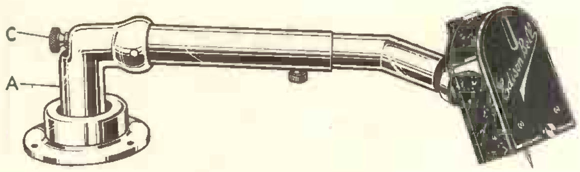


Fig. 23.—THE EDISON BELL PICK-UP.

Details are as follows :—
D.C. Resistance, 1,000 ohms.
Impedance at 1,000 cycles, 1,800 ohms.
Average output, 0·5 volt.
Volume control recommended, 50,000 ohms.
Needles recommended, Edison Bell " Electric chromic."

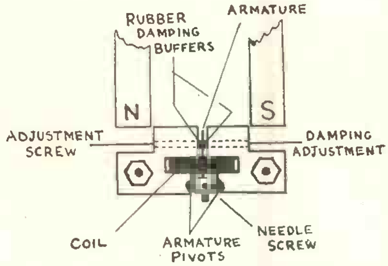


Fig. 24.—DETAILS OF THE EDISON BELL PICK-UP.

variable resistance connected across the series condenser used in a choke-fed loud speaker arrangement, as shown in Fig. 18.

Special Intervalve Transformers

By far the best way of introducing tone control in this instance is to use one of the special intervalve transformers which are produced for this purpose and worked in conjunction with a variable resistance; this then enables the correct circuit arrangements to be reverted to in the case of radio.

Tone Control in the case of Triode Output Valves

If it is desired to restrict the upper register in the case of triode output valves, this can be done in a number of ways, the first being, as we have already seen, by connecting fixed or variable resistances across the pick-up leads. Secondly, a variable resistance can be introduced across the primary of the intervalve transformer, or a combination such as mentioned in connection with the pentode valve used across the loud speaker or primary of the output transformer. The special tone compensating transformer can, of course, also be used in this case if desired, and this will provide excellent control of tone.

Bass Cut-Off

It is very unlikely that it will become necessary to provide a bass cut-off where gramophone reproduction is concerned, but if this should be desirable it can be accomplished by means of a

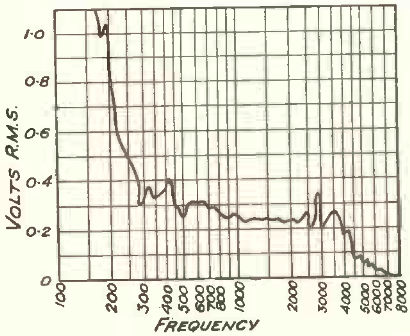


Fig. 25.—AVERAGE CHARACTERISTIC CURVE OF EDISON BELL PICK-UP.

SERVICING NOTES

However good a pick-up is, it will probably require slight adjustments from time to time with constant use, as little troubles develop, and we give here some advice on tracing faults with hints on how to overcome them.

Loss of Volume

This, perhaps, is one of the most common faults in company with complete absence of output, and can usually be traced to the armature laying over on one of the pole-pieces. Unless the rubber damping and the armature pivot have become perished, and need renewal by the makers of the pick-up, the difficulty can usually be overcome by slackening off the screws holding the pole pieces in position and holding these fairly tightly together whilst the screws are tightened up again.

Damping Adjustment

The damping adjustment at the extremity of the armature should also be slackened off whilst this is taking place, and, with care in fixing this back in position, the pick-up should now be in working order again. The illustrations given of the Marconiphone No. 17 Pick-up

Fig. 26.—The Varley "Mass Suspension" Pick-up.

Details are as follows :—

D.C. resistance, 2,110 ohms.

Impedance at 1,000 cycles, 9,000 ohms.

Average generated mean voltage, 0·6 volt R.M.S.

Recommended volume control, 250,000 ohms.

Recommended needles, loud tone.

Fig. 27.—The G.E.C. "Unit" Pick-up.

A special feature of this pick-up is the absence of pole pieces ; the armature is suspended directly between the magnet poles. Details are as follows :—

Average output, 1 volt R.M.S.

Recommended volume control, 50,000 ohms.

Recommended needles, H.M.V. loud tone.

assembly and others of a similar type, will make this quite clear. The Edison Bell accessory has an excellent arrangement of variable damping, the screws controlling this enabling the armature to be very nicely centred without the slightest difficulty; it is advisable to keep the damping as light as possible consistent with suitable results.

There are, of course, exceptions to the general rule in pick-up design, and one of these is the "Varley" ; the armature in this case is rather larger than usual, but it is nicely suspended, and quite a number of adjustments are possible in connection with the damping, thus ensuring satisfactory results from every point of view.

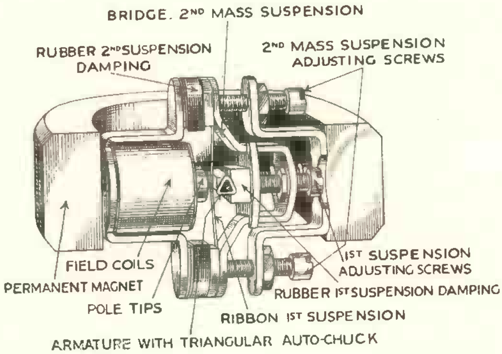


Fig. 28.—Details of the Varley "Mass Suspension" Pick-up.

Testing Pick-up Coil for Continuity

If the above adjustments do not overcome the difficulty where loss of output is concerned, the pick-up coil should be tested for continuity in the usual way with a voltmeter or headphones in series with a battery. If headphones are used, a record should be set in motion on the turntable and the pick-up placed in the playing position ; if the pick-up is in order, quite good headphone signals should be heard when these are connected across the leads.

Testing Magnet for Weakness

With the coil to all intents and purposes in good order, in addition to the armature adjustments being satisfactory, the magnet should be tested for weakness and the leads for a short to earth if poor results still persist. A good test for the magnet is to put a screwdriver or similar article across the poles, when it

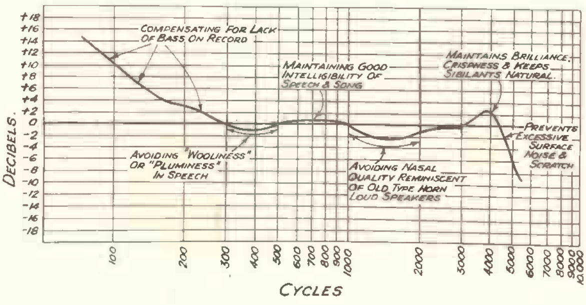


Fig. 29.—Average Characteristic Curve of Varley Pick-up.

should be found that it should be possible for it to carry its own weight. In most cases where a metal carrier arm, etc., is used this is earthed, and tests should be made to see whether one of the leads is in electrical contact with the pick-up head, especially in the case of some revolving pick-up heads. If so, of course, this should be suitably insulated.

Faulty Volume Control

With the pick-up disconnected from its associated gear and apparently in order, the next thing which should receive attention when there is an absence of results is the volume control. This may have become open-circuited in the case of a wire-wound component, due to too much pressure of the moving member, or, of course, the latter may not be making contact with the resistance element, which the necessary adjustment will put right. Leads between pick-up and amplifier should be tested for a short or short to earth and any switch contacts or connections examined.

A mains receiver or amplifier may utilise a cathode resistance in order to bias the first valve, and in this case one side of the pick-up is usually in direct connection with " earth." This should be taken into consideration when the above tests are made. When a suitable instrument is available the pick-up coil can be measured for D.C. resistance to ensure that this is in perfect order, and this should be approximately as given by the makers.

Loud Hum

Where a loud hum is experienced this can invariably be traced to a break in the pick-up circuit, and this is usually associated with a small and distorted output; continuity tests should be made and leads or coil renewed accordingly.

Rattle or Buzz in Reproduction

Reproduction that is accompanied by a fuzziness, apart from where a record is badly worn, or the loud speaker is out of adjustment, emanates very often from a pick-up which has collected iron filings between its pole pieces, and these should be carefully removed.

Other Types of Pick-ups

There are other types of pick-ups besides those dealt with in this article, but the above notes cover all types now in commercial use.

The " Electrostatic," or condenser pattern, and the " Moving Coil " type offer possibilities from a purely theoretical standpoint. It is impossible to predict future developments in this, as in most other branches of this intriguing subject.

ELECTRIC GRAMOPHONE MOTORS

By J. H. A. WHITEHOUSE

SECTION I—HIS MASTER'S VOICE MOTORS

The Governor

NO survey of the action or notes on the repair of any electric motor would be complete without a special notice on their governor (Fig. 1).

The governors used in the motors of to-day are the result of concentrated research extending over many years on the governor, which should be treated as a delicate instrument, however robustly it may appear to have been made.

Chief Parts of the Governor

The chief parts of the governor consist of a steel spindle, to one end of which is affixed a brass collar, to which are attached the ends of the three springs on which the governor balls are mounted. The other ends of these springs are secured to a flange which slides up and down the rotating spindle, and on the inner surface of which pressure is exerted by means of the leather pad of the speed regulating lever.

How the Governor Works

When the spindle is rotated, centrifugal force, acting on the governor balls, causes the balls to fly outwards, drawing the movable flange inwards against the pressure of the leather speed regulator pad (Fig. 2). If the speed regulator pad were withdrawn, the motor would speed

Fig. 1.—Details of the Governor.

Showing the grub screw securing the fixed flange to spindle.

Fig. 2.—Details of the Governor.

Showing the balls out and moving flange moved up the spindle towards the fixed flange.

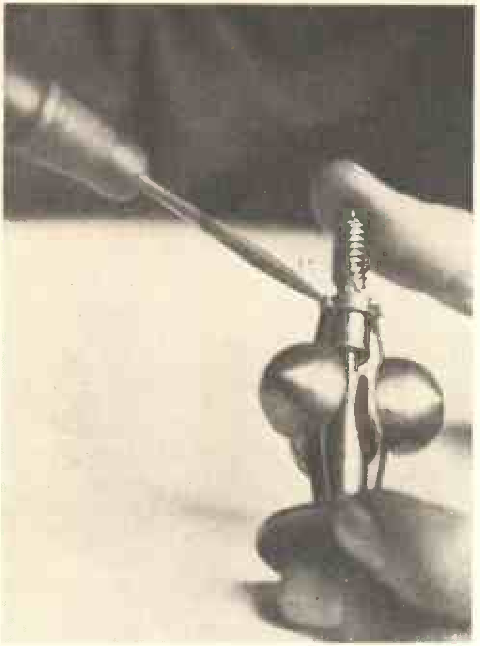


Fig. 3.—DETAILS OF THE GOVERNOR.
Tightening the ball springs.

FIG. 4.—DETAILS OF THE GOVERNOR.
Showing method of testing spindle.

up, the balls expanding to their maximum position, drawing the flange inwards as far as it would go. Any pressure on the movable flange, therefore, would tend to slow the governor down, and by preventing the movable flange from moving inwards, prevent the governor balls flying outwards.

Movement of the Governor Flange

The action of the governor, therefore, depends upon the continuous interaction between the pressure of the speed regulator pad on the movable flange and the force exerted by the governor balls attempting to draw the flange inwards against the pressure of the leather pad of the speed regulator lever. This interaction is constant, and in a well-designed governor the movement inwards and outwards on the governor flange should be very slight indeed.

Causes of a " Crazy " Governor

If this movement is not slight, that is to say, if a reciprocating action takes place, this may be due to a number of causes. If, for instance, the friction pad of the movable flange of the governor is not properly lubricated, the interaction between the movement of the flange and the pressure of the pad may develop into a periodic jerky action resulting in a whirring sound which has, among other symptoms, been described rather loosely as a " crazy " governor.

There are, however, other points which will contribute to a governor going " crazy." A slight displacement of the springs secured to the fixed and movable flanges may cause this effect, and the screws attaching the spring to either end should be examined for looseness (Fig. 3).

If the balls themselves are found to be loose on their mounting on the springs, an oscillatory motion may be set up, which will give the characteristic whirring sound mentioned above.

If due to some roughness on the spindle of the governor itself, the sliding action of the movable flange is not absolutely perfect, and the sliding flange and fixed flanges are not in perfect alignment, a similar effect may be noted.

Further, if the motor is suddenly stopped by grasping the turntable instead of employing the gradual action of the brake the governor springs may be twisted slightly.

How to Test the Governor

One simple method of testing a governor is to withdraw the speed regulator pad from the flange, and having seen that the balls are firmly secured to the springs, very slightly slack off the screws securing the ends of the springs to the fixed and movable flanges. The governor should then be spun rapidly through the medium of the turntable spindle, and allowed to die down to a stationary position, when the screws securing the spring should be retightened in exactly the same position they occupy when the governor has ceased revolving. It will be found that in many cases this will overcome the trouble. If, however, this is not so, it may be that the governor spindle itself has become worn, and that the action of the sliding sleeve is not true or in perfect alignment with the fixed sleeve, or that it is encountering friction, possibly very slight, somewhere as it travels slightly backwards and forwards over the spindle.

Fig. 5.—The Motor should be Gently Turned by Hand to Detect any Mechanical Jam or Friction.

How to Test for a Worn or Bent Spindle (Fig. 4).

The best plan is to remove the governor, instructions for doing which will be given for the various motors. When this has been done the governor spindle should be withdrawn by unscrewing the fixing screw which secures the fixed flange to the spindle, then holding up the two sleeves by the flange of the movable sleeve vertically, allow the spindle to drop through the movable sleeve into the fixed sleeve. If the spindle does not drop through gently, without touching the edge of the lower fixed sleeve, the governor is out of adjustment and it is possible that the spindle has been strained.

The spindle should be examined carefully for any " high spots " or traces of

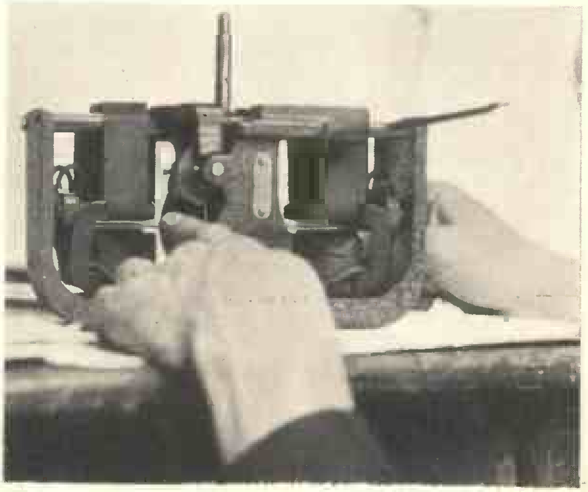


Fig. 6.—Looking for a Bent Disc between Magnet Poles.

friction, which should be gently rubbed down with a hone.

The End Bearings

A further cause of trouble may be due to the fact that the end bearings (Fig. 5), in which the governor locate, are exerting too much or too little pressure. In addition to this, the lining up of the spiral gear at the end of the spindle should be carefully observed with relation to the gear wheel on the spindle of the motor.

Never hold the governor by the balls. If the governor flange is held still a slight amount of play between the movement of the turntable spindle and the governor is allowable in most motors.

The Importance of Correct Lubrication

There is an excellent reason for this. Certain types of oil which can be used on larger types of machinery contain slightly corrosive elements. This may seriously interfere with the smooth working of so delicate a piece of apparatus as the governor by producing corrosive effects which may become noticeable until after only a few months of work. It should be perfectly clear, too, that any kind of grease or oil which is likely to solidify in cold weather will produce slowing-up effects and possible sluggishness, especially if the instrument is switched on after some considerable period of not having been used in a cold room.

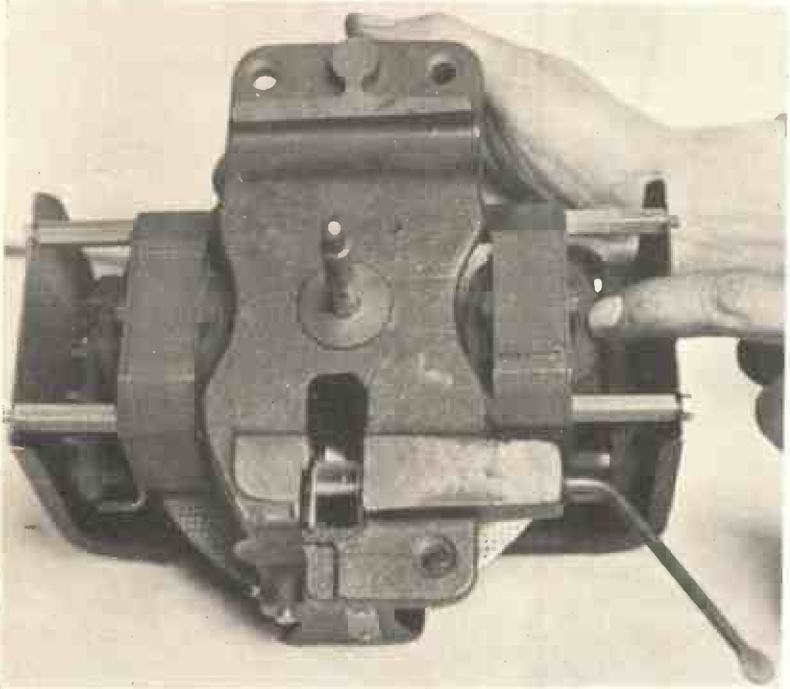


Fig. 7.—Top Side View of the Model 91 Motor.

THE HIS MASTER'S VOICE INDUCTION DISC MOTORS

In the His Master's Voice induction disc motors with their extremely simple design, a serious stoppage is only likely to be either in the supply to the motor, or due to some mechanical jam: for instance, a confusing form of breakdown is if the speed regulator lever slips off the screw which adjusts its height below the motor board, thus allowing the pad to exert its maximum pressure on the governor flange. If the mains is switched on to the motor and the motor will not revolve, the first thing that should be done is to turn the motor carefully by hand; this should tell at once whether there is a mechanical jam anywhere or whether something in the electrical circuit has got to be looked for (Fig. 5).

Disc Slightly Bent

The only other type of trouble which might be encountered and which is very simple to put right is that due to the action of the electrical current in the disc or that force has been used at some time or other.

causing the disc to become slightly bent. The application of careful pressure in the opposite direction by turning the disc slowly and looking through the gap of the magnet through which the disc passes will put this right (Fig. 6).

When oiling a motor it is important that the upper bearing should not be neglected. This is situated below the turntable.

Electrical Defects

Generally speaking, the electrical defects which are likely to be encountered are either the burning out of a coil, in the case of an alternating current induction disc motor, or the possible short-circuiting of a coil down to earth, due to a breakdown of resistance caused possibly by atmospheric conditions. This is unlikely, but it is a thing which should be tested for; in no case should there be a reading to earth (frame of motor) from any of the electrical windings of His Master's Voice induction disc motors.

HIS MASTER'S VOICE MODEL 91

The first His Master's Voice induction disc motor (Fig. 7) was adjustable only for one voltage, that is to say, it was supplied for the voltage which it was ordered to be worked, and could not be adjusted to any other voltage. Later models of these motors are supplied with adjusting links, details of which will be given later. It should be remembered, too, that induction type motors cannot be used on any frequency other than that for which they are designed, and that a serious hum or sluggishness may be caused by the fact that the A.C. mains to which the motor is connected have a frequency incorrect for the motor.

The Model 91 was the first His Master's Voice induction disc motor and was employed on the Model 551 electric reproducer, and on Acoustics Model gramophones with electric driven turntables. The Model 91 was also employed on Model 551 electric reproducer and radio gramophone No. 520.

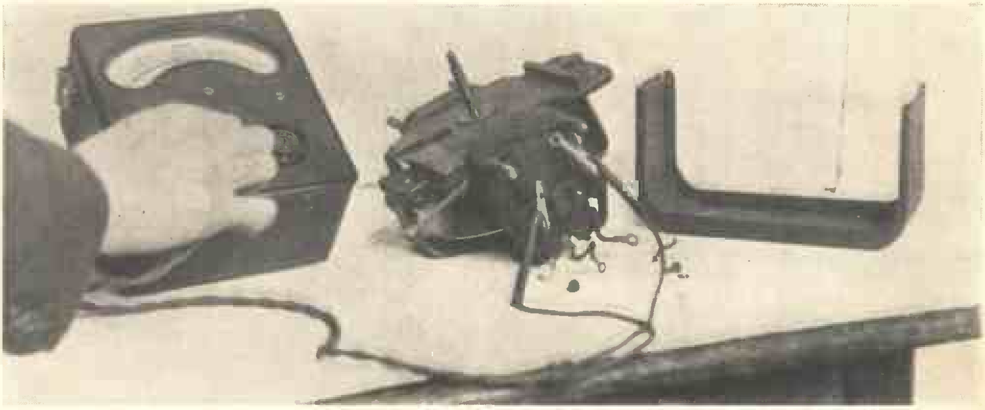


Fig. 8.—Measuring the Resistance of Top Coil.

The D.C. resistance of each upper coil should be 17 ohms. An "Avometer" may be very conveniently used for this test.

HOW TO RECOGNISE THE TYPE 91 MOTOR

This motor is the only H.M.V. induction disc motor with its two magnet units directly opposite to each other and which has no condensers associated with it.

How the "91" Motor is Arranged

The two magnet units, which are bolted on a cast-iron frame, act on a copper disc attached to the spindle. Each magnet unit consists of two electro-magnets, separated by a small air gap, in which air gap the disc rotates. The upper magnet of each unit carries what is known as the upper or re-active coil and the lower magnet two non-reactive coils.

Lewcos

REGD.

Radio Components

Fundamentally sound in every sense, Lewcos precision-made components owe their superiority to their creators' long experience as first-class wire-manufacturers. All reputable dealers stock and confidently recommend Lewcos components of every type.

Descriptive Literature of the components you need will be supplied on demand to Radio Publicity Dept. N.

THE LONDON ELECTRIC WIRE COMPANY AND SMITHS LIMITED, CHURCH ROAD, LEYTON, LONDON, E.10

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SERVICING THE BAIRD "TELEVISOR"

ELECTRIC GRAMOPHONE MOTORS

MAKING A START IN AMATEUR TRANSMISSION

1/-

Part 24

IN 32 WEEKLY PARTS

THE THIRD VOLUME OF "NEWNES COMPLETE WIRELESS" IS COMPLETE WITH THIS PART

BIND IN THE PUBLISHERS' AUTHORISED CASE

With this part the third volume of "Newnes Complete Wireless" is complete. Lose no time in getting your loose parts of this invaluable work bound. Any part work in constant use, no matter on what quality paper it is printed, is sure to wear out in time, and as long as parts remain unbound they are liable to get damaged or destroyed.

Imperial Blue Embossed Cloth with gilt lettering and design - each 2/6

This price does NOT include the cost of binding.

For Details of SPECIAL BINDING OFFER SEE BACK PAGE

Binding Cases are obtainable at all Newsagents and Bookstalls, or 2/9 post free from George Newnes Ltd., 8–11 Southampton Street, Strand, London, W.C.2.

PART 24.

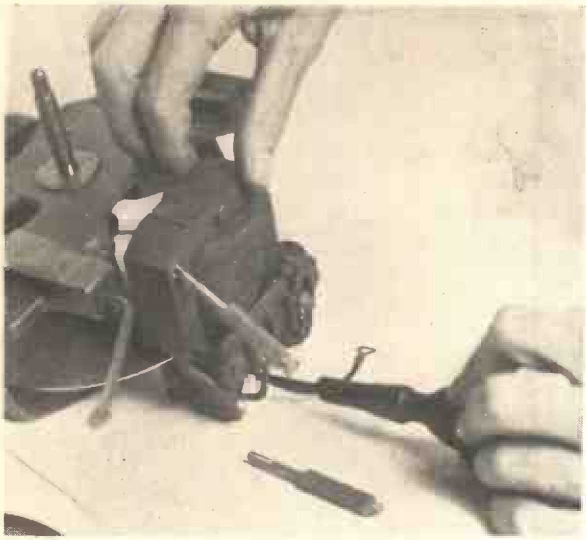


Fig. 9.—REMOVING THE MAGNET UNIT OF TYPE 91 MOTOR.

Continuity Testing

Continuity testing for the coil can be made from the two moulded terminal blocks, situated on each magnet unit, which is accessible when the metal screen round the motor has been removed. Two types of the 91 motor were manufactured, one for 200 to 240 volts, the other for 100 to 110 volts, indicated on a small metal plate, alternating current 50 to 60 cycles periodicity in both cases.

Electrical Details of the 200 Volt Type 91 Motor

The electrical data for the 200 to 240 volts Type 91 motor is as follows :

Where to Measure the Coils (Fig. 8)

The D.C. resistance of each upper coil is 17 ohms. To measure this disconnect the leads from the terminals and measure leads emerging from the top coil (Fig. 9). Each pair of lower coils have a D.C. resistance of 510 ohms, measured at the two leads emerging from the coils separated from the leads from the top coil. The total resistance of the whole motor, that is, the two upper coils and the two pairs of lower coils is 16 ohms, measured at the terminals with all leads reconnected to the terminals.

Electrical Details of Type 91 Motor for 100 to 110 Volts

Each upper reactive coil, 4 ohms ; each pair of lower non-reactive coils, 120 ohms ; total resistance of the motor measured at the point where the mains are connected to it, 7·25 ohms.

How to Dismantle a Model 91 Motor

It is unlikely that the motor will have to be completely dismantled, but if this is necessary, proceed as follows :—

(1) Disconnect the earth wire to the motor and the lead from the motor to the switch or radio chassis, as the case may be.

(2) Remove the motor from the motor-board, noting carefully the thickness of the packing washers so as to ensure the correct turntable height on reassembly. *This is important to remember.* If the motor is uneven or at the incorrect height from the underside of the motor-board, uneven running may result, or it may be found that the turntable is either too high or actually fouling the upper side of the motor-board.

(3) Remove the metal shield round the motor, but slacking off *nuts only*. This will give access to the terminal plates.

(4) In order to remove a magnet unit (Fig. 9), if this is found necessary for replacement or inspection, the three screws, two long hexagonal and one shorter screw, should be removed from each magnet unit. Do not disturb the bolts which clamp the laminations and the magnet units together, otherwise some difficulty will be found in readjusting the magnet gear ; hum may occur, due to loose laminations.

(5) Remove the coil spring which holds the leather pad in contact with the governor friction flange, then remove the governor brake lever by slacking off the screw which secures the bent metal leather pad bracket to the flattened portion of the brake lever and remove the governor as follows.

Fig. 10.—Taking Out the Governor from the Motor.

How to Take Out the Governor (Fig. 10)

Looking at the motor on the governor side, slacken the screw holding the right-hand governor bearings in position in the cast metal frame of the motor. Then slide the entire governor to the right until the left-hand bearing is free. The governor may now be removed by holding the right-hand pivot and withdrawing the governor towards the left and outwards (Fig. 10). *Do not pull the governor out by means of the springs or balls, and take the greatest possible care not to drop it or put it in a place where it is likely to be damaged.*

How to Remove the Disc

The disc and spindle may be removed by slackening the grub screws which secure the disc and the governor worm wheel and the turntable spindle and by withdrawing the spindle. *When the spindle has been withdrawn, it is of the utmost importance that the little metal bearing ball situated in the lower bearing is not lost. This can easily be done if watch is not kept for it.*

MODEL 85 INDUCTION DISC MOTOR

This motor (Fig. 11) is similar in many ways to the Model 91, and will be found on certain models of the Model 520 Radio Gramophone and the Model 551 Electric Reproducer. Its main difference from the 91 Motor, however, is that two condensers will be found connected to it, mounted on the underside of the motor-board, and that the magnet units are adjacent to each other (see Fig. 11A).

This motor is adjustable for two voltage ranges—100–125 volts, 40–60 cycles per second, and by readjusting the links from 200–250 volts, 40–60 cycles.

The Electrical Data of the Model 85 Motor

The electrical data of the Model 85 motor is different from the Model 91. The resistance of each top-reactive coil is 18 ohms and the resistance of each non-reactive coil 1,000 ohms. The capacity of each condenser should be 1 mfd. each. The total resistance of the motor when it is adjusted for 100–120 ohms should be 9 ohms. The total resistance of the motor when adjusted for a supply of 200–220 volts should be about 36 ohms.

As with the 91 motor, there should be no electrical connection between any of the windings and the motor frame; if this is so, it is due to a breakdown of insulation.

How to Dismantle the Model 85 Motor

(1) Disconnect all supply and earth leads to the motor terminal block.

(2) Disconnect leads to the condensers and remove the motor from the board by withdrawing the three motor-securing screws.

(3) Remove the metal screen round the motor.

(4) Remove the four screws, securing each magnet unit to the motor frame, taking care not to disturb any screws whose function is to clamp the laminations

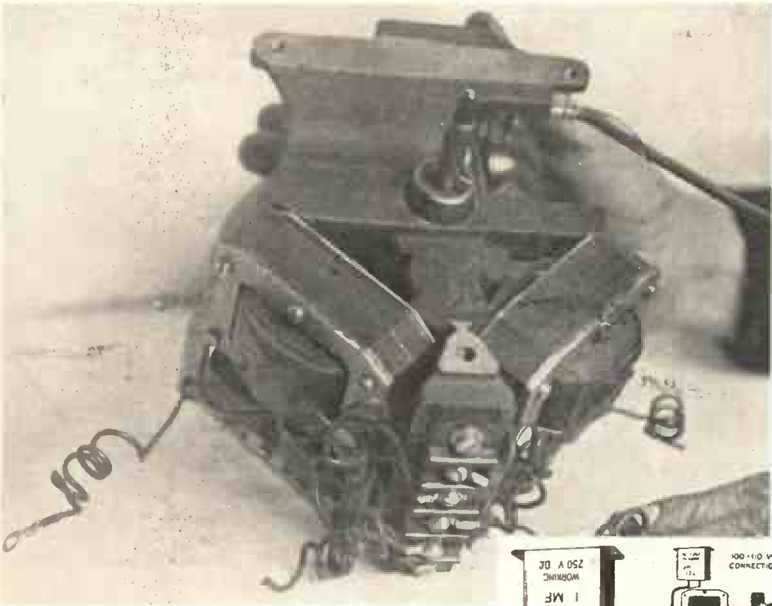


Fig. 11.—Top Side View of Type 85 Motor.

and not secure the magnet units to the motor frame.

(5) The governor brake lever will be found in two parts connected together by a screw collar. If it is required to remove the lever the collar should be taken apart. The governor should be removed in a similar manner to the instructions given with the Model 91.

Special Notes with Regard to the Re-assembly of the Model 85 Motor

Special attention should be given to the following points. Be certain that :—

(1) The steel ball is in position in the lower turntable spindle bearing before inserting the turntable spindle.

(2) The disc and the governor worm-gear grub screws locate in the special dimples provided for them in the surface of the spindle. This is important.

(3) The driving disc is properly aligned in the centre of the air gap between the magnets, by the adjustment of the lower bearing screw beneath the lower bearing spindle. This should be done after replacing magnet units.

(4) Make sure that the motor-speed control lever is correctly located on the motor-speed control screw and that there is no possibility of its slipping off and thus jamming the motor.

The Connecting Collar

It is also important to see that the connecting collar, connecting the two parts to the lever, is tightly screwed up.

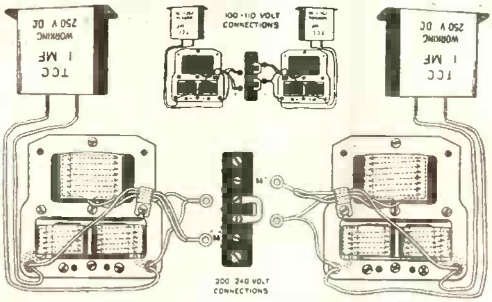


Fig. 11A.—The His Master's Voice Induction Motor Type 85.

Note that the mains are connected to terminals M.M. in both cases.

THE HIS MASTER'S VOICE 82 UNIVERSAL MOTOR

This motor was used on the Models 1, 2 and 10 Automatic Acoustic Gramophones, and on Models 12 and 15 Automatic Electric Reproducers, and on certain of the electric drive Acoustic Gramophones.

The motor itself is a 40 v. universal motor operating on either A.C. or D.C. The supply voltage is reduced to 40 volts from whatever value it happens to be by a calibrated resistance which is fitted with the motor.

How to recognise the Type 82 High-speed Squirrel Cage Motor (Fig. 14)

This motor is entirely different from the His Master's Voice induction disc motors, as the governor is mounted on the same spindle as the armature, which is protected by a pressed-out metal shield secured to the cast-iron frame of the motor close to the mains plug by means of a single screw; the armature spindle on which the governor is mounted is geared by a right-angle gear to the turntable spindle; the motor is, of course, supplied with an adjusting resistance, which is normally found below the bottom of the cabinet. The brass rod of this resistance is marked according to voltage (see Fig. 12).

Measuring Motor Resistance

If the motor resistance is measured across the two brass pins of the motor supply plug, the readings should vary round about 70 ohms; if the reading is higher than this, it is probable that the brush pressure is insufficient, and if a marked flick of the meter is shown as the motor is revolved, this may be due to a burnt-out armature segment which should be tested for across the opposite armature segments as the armature is revolved. The brush pressure may be increased by moving the end of the brush lever spring that locates in a small hole on the insulating brush carrier into a hole, which will be seen further towards the commutator (see Fig. 13).

It is very important that if this motor is tested on the bench it should be connected to the mains through the adjusting resistance which may still be in the cabinet. When testing on the bench, therefore, a lead should be taken from the black motor socket and not direct from the mains, otherwise the motor may be burnt out.

Lubrication

The same general points in connection with lubrication should be observed with this motor with regard to the use of unsuitable lubricants. It is very important that the commutator should be kept free of oil, otherwise sparking may take place, which results in wearing of the commutator

Fig. 12.—Adjusting the Resistor of the Type 82 Motor for the Voltage of the Mains.
Showing cover removed.

and unsatisfactory running conditions generally. Special attention is paid to the lubrication of the special friction cup, which may be found over the sliding flange of the governor.

This flange is not always fitted, but if it is fitted, the following directions should be followed closely:—

Carefully mark the position of the safety stop before slacking it away to allow the friction cup to come away from the governor flange, leaving an opening for the lubrication. This is important, so that the friction cup can be replaced exactly as it was before. Apply a very small

Fig. 13.—Adjusting the Brush Pressure Spring.

was marked before it was slacked off. An examination of this stop will show that it is intended to prevent the motor running at an excessive speed, with possible damage to the governor balls and spring.

How to Examine the Brush Gear and Commutator

Set the motor running by means of an extension lead from the cabinet resistance and lightly press a piece of fine glass paper against the surface of the commutator while the motor is running. Under no circumstances use emery paper, as this has a metallic content which may cause short circuiting. Do not use severe action when papering down the commutator, as if too much copper is taken off the segments of the commutator the mica divisions

quantity of His Master's Voice motor grease into the interior of the cup, and a little His Master's Voice oil; then replace the safety stop and flange in their original positions. Under no circumstances attempt to run the motor until the safety stop is screwed into position, which

between the sections of the commutator may protrude, providing a possible source of sparking. When it is found that the commutator is very badly pitted or scored, no attempt should be made to remove these marks with glass paper; the correct method is to "skim" the commutator with a special tool, which is the work of an expert.

Fig. 14.—Type 82 Motor with Cowl Removed.

How to Clean the Brushes

Switch off the motor; disconnect from the mains. Then pass a narrow strip of fine glass paper about $\frac{1}{4}$ inch wide round the commutator with the glass surface pointing outwards; then with one brush at a time resting on the glass sur-

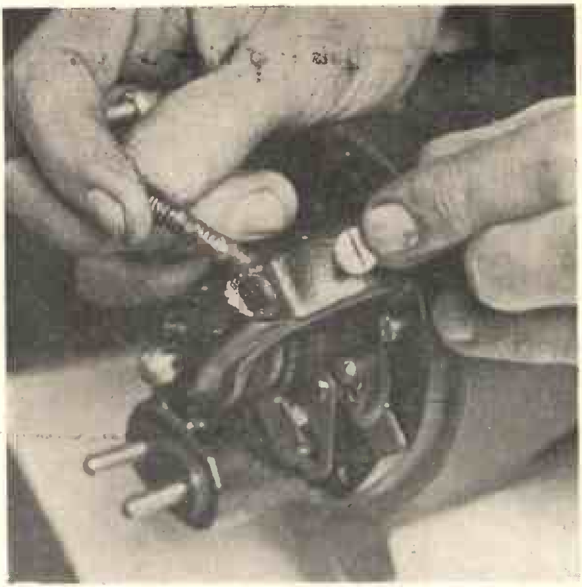


Fig. 15.—Examining the Main Bearing Greasing Wick and Spring.

holders, they should be replaced, and the new brushes bedded into the shape of the commutator by the process described.

It is very important that the brush holders should be firmly screwed to the framework of the motor.

How to Oil the Bearings

Special attention is paid to two other oiling points in the motor :—

(1) For oiling the bearings of the main shaft between the governor and the armature.

(2) For oiling the main bearing at the commutator end.

For Oiling One End of the Bearings (Fig. 15)

Both these greasing points are concealed underneath brass caps, which screw over the hole by which the grease is communicated to

face of the paper move the commutator this way and that by means of the strip of paper, so that each brush takes up the correct curvature of the armature. If brushes are worn to a considerable extent or show any great looseness in the brush

the bearing. These should be removed periodically ; in them will be found a spring, and at the end of it a small wick ; the whole should be encased in grease. It sometimes happens that this grease dries up ; if this is so, the spring

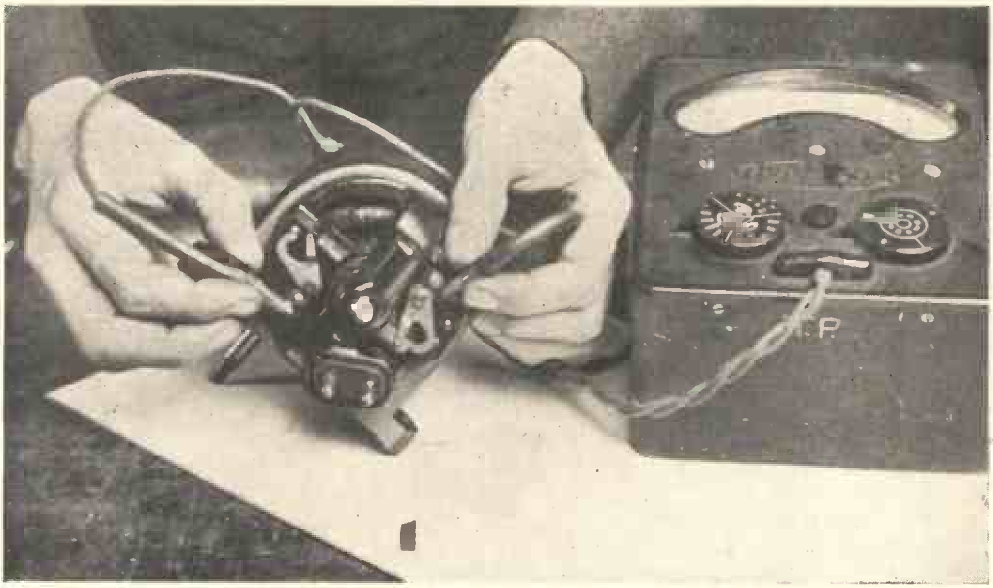


Fig. 16.—Checking the Field Winding of the Type 82 Motor.

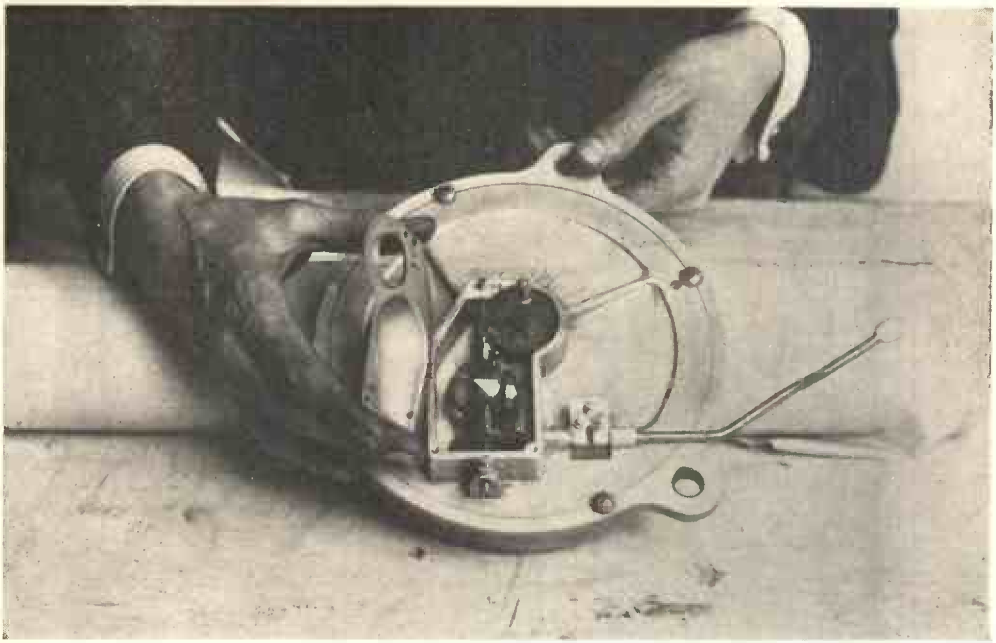


Fig. 17.—The His Master's Voice 521 D.C. Motor with Governor Removed.

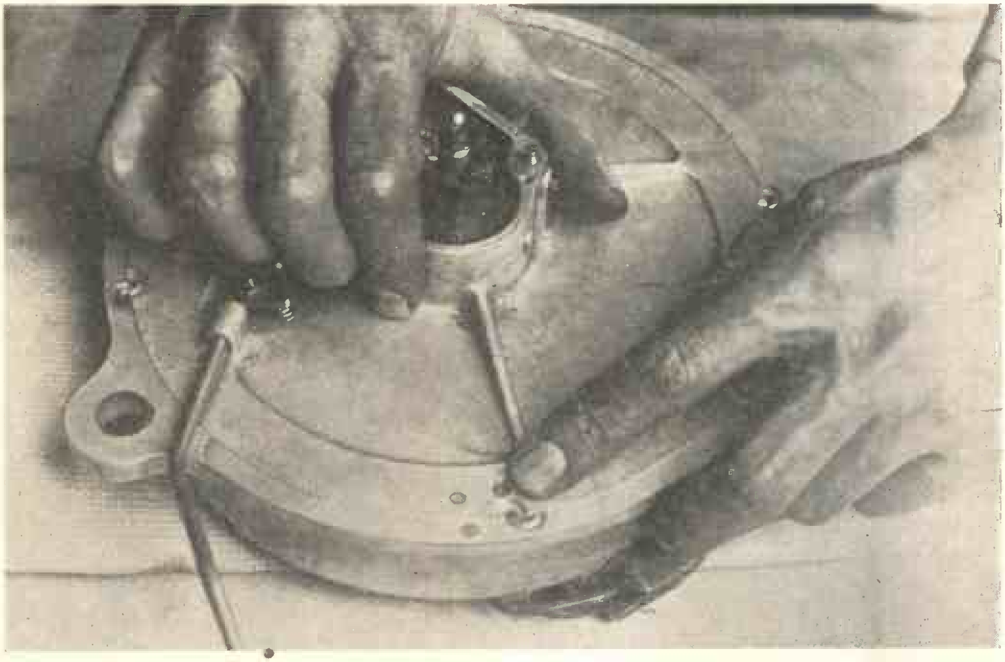


Fig. 18.—Lining up the Top Plate with the Case.
The two special oval locating marks should be opposite each other.

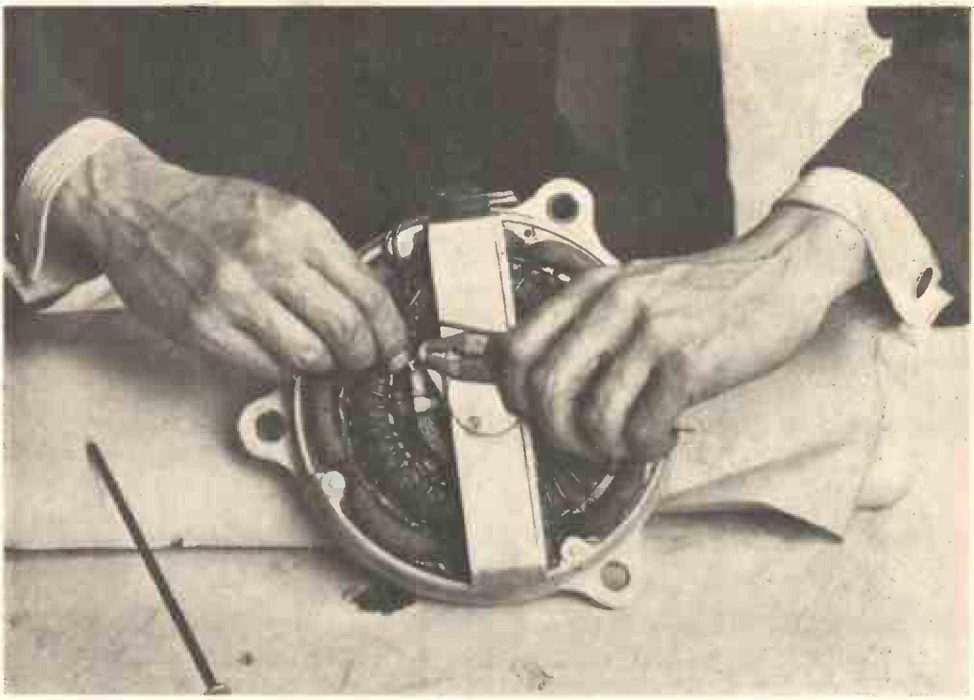


Fig. 19.—Adjusting the Brush Pressure.

This is done by slacking away the slotted screw and the nut securing the brush bearing and moving the brush pressure lug about until a suitable spring tension has applied the necessary amount of pressure on to the brush.

Fig. 20.—This shows the Spring Oil Nipple for the Bottom Bearing.

and the wick should be carefully soused in oil and re-greased, if necessary, the end of the wick being manipulated with a pair of pliers and softened so that it becomes absorbent again, so that when pressing down on the revoling bearing it communicates the grease held by the spring.

THE SPECIAL D.C. MOTOR USED ON "HIS MASTER'S VOICE" MODEL 521 RADIO-GRAMOPHONE FOR DIRECT CURRENT

How to recognise the Motor (Fig. 17)

This motor is a wide shallow motor in an aluminium casing with a very wide rotating armature, the field coils being mounted round the edge of the motor. The motor receives its main supply from the chassis through a black plug on the right-hand side of the chassis looking at the back, and red and black flex, which has in series with it a motor voltage adjusting resistance on the right-hand side of the back of the front wood panel.

The motor field winding and armature are in series.

How the Current Passes through the Motor

The current enters the eight-field magnet coils *viâ* motor plug pins "B" (see Fig. 25) and leaves the magnets by the wire connecting the last magnet unit to brush "A," whence it goes back again to the other motor supply pin plug. The D.C. resistance of the eight-magnet coils when measured from pin "B" to brush "A" should be approximately 35 ohms. The total resistance of the motor, however, will vary as the motor is rotated between 100 and 110 ohms. It should be noted that the pressure of the brushes on the armature will affect this reading. If the brushes are not pressing sufficiently the reading may be very much higher, which will give an indication that the brush pressure is insufficient, or that the armature and commutator is unduly dirty.

What to do if the Motor Fails to Revolve

A continuity test can be taken on the pins of the motor supply plug, having removed the other half. This, as stated above, should be between 100 and 110 ohms. If no reading is given, the brushes should be examined for brush pressure, and, if necessary, the armature coils checked for continuity. If when rotating the armature slowly while making this measurement, a kick on the resistance meter is given, it is possible that one section of the armature is burnt out, and a test should be made across opposite segments of the commutator round the commutator until the faulty section is found. It is better to return this motor for repair if this is so, as it is an expert coil winder's job to replace a defective armature winding.

> WARNING.—As with all motors having an adjusting resistance, if this motor is taken out of the cabinet for testing purposes, it should not be connected directly to the mains, otherwise the motor will burn out. It should be connected by means of an extension lead to the variable resistance in the cabinet. That resistance is arranged and calibrated so that the motor always receives 50 volts at the terminals of the motor when it is revolving.

How to take out the Armature

Unscrew the top plate retaining screws which can be seen in Fig. 26, then separate the brushes by the fingers of the left hand and withdraw the armature complete with the top plate. Be very careful not to lose the small ball in the lower bearing; if this is lost, the armature will not fit correctly back into position when it is reassembled. It is important when reassembling the armature and top plate that the two special oval locating marks (Fig. 18), one on the top plate and the other on the frame of the motor, are opposite to each other. These are placed there in order that the top plate may be returned in its correct position.

How to Adjust the Brushes

The best way to adjust the brushes is to slack away the slotted screw and the nut securing the brush bearing (shown in Fig. 19), and move the brush pressure adjusting lug about until a suitable spring

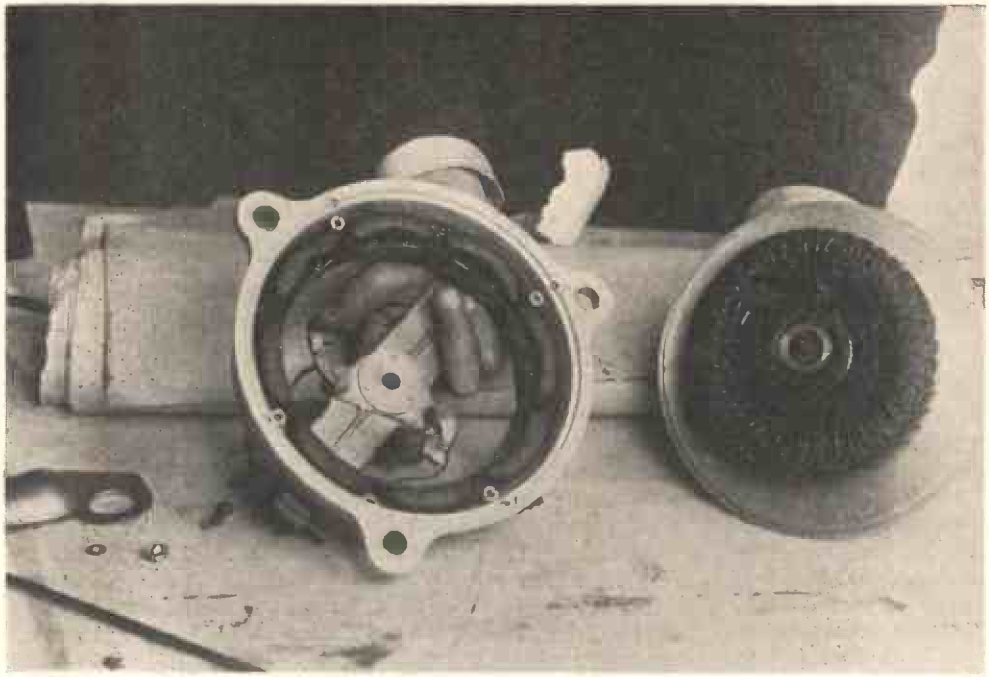


Fig. 21.—Removing the Top Plate to get at the Armature.
Showing the fingers holding the brushes apart for reassembly.

Fig. 22.—Checking up the Connector Windings.

Fig. 23.—How to Clean the Armature with Glass Paper.

Fig. 24.—Checking the Total Resistance of the Motor.
This should be done while slowly revolving the armature.

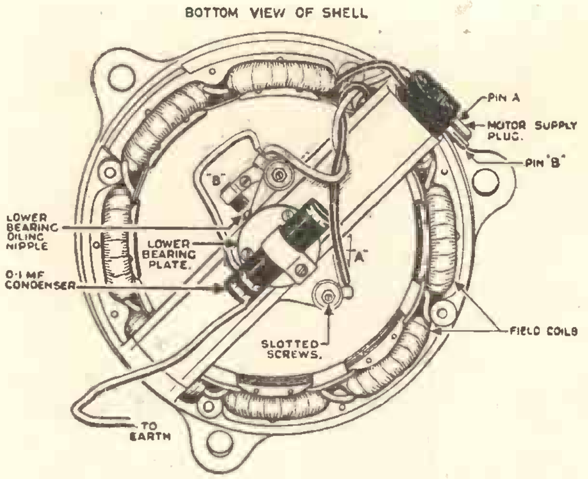


Fig. 25.—THE UNDERSIDE OF THE 521 D.C. MOTOR.

tension has applied the necessary amount of pressure on to the brush.

How to Replace Brushes

These brushes are kept in position by means of a brush retaining screw and nut. This must be slacked away in order to get the old brush out and to fit the new brush. If the armature is dirty or pitted, it can be cleaned by glass paper, as has been previously described for the His Master's Voice High Speed Universal Motor. Under no circumstances use emery paper.

Lubrication

The governor assembly can be lubricated from the top of the motor by the removal of the cover plate. Be very careful not to disturb the governor-bearing screws, which will be distinguished from those securing the cover plate, as they have smaller heads. These should not be touched. To lubricate the lower bearings a spring nipple will be found just above brush "B" (shown in Fig. 25). The top bearing can be oiled when lubricating the governor by removing the cover plate.

How to Check the Adjusting Resistance of the Motor

The D.C. resistance of each side of this motor adjusting resistance should be about 500 ohms, each measured from the metal strap at either end of the coil.

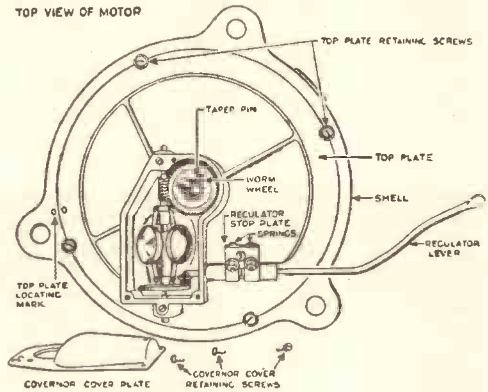


Fig. 26.—TOP VIEW OF THE 521 D.C. MOTOR.

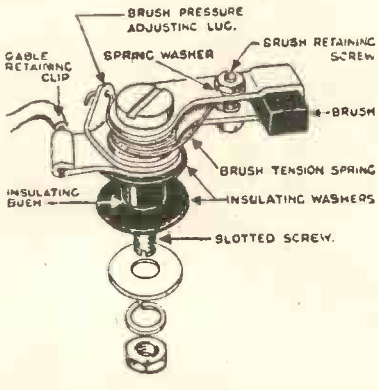


Fig. 27.—THE BRUSH ASSEMBLY OF THE 521 D.C. MOTOR.

Condenser

A 1-mfd. condenser is connected between brush "B" and the wire earthing the motor of chassis and pick-up of the instrument to reduce any interference due to sparking. If this condenser is broken down, interference may be caused to the motor with a possible leakage to earth of current. The best plan, if it is impossible to test this condenser, and if it is suspected, is to substitute another. Details of other popular makes of electric gramophone motors are given in another article.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION XII—THE VALVE: AMPLIFICATION AND DETECTION

WE saw in Section III of this series that wireless signals are alternating signals of sine wave form. We have to modify this statement, however, before we can discuss completely the action of a detector valve.

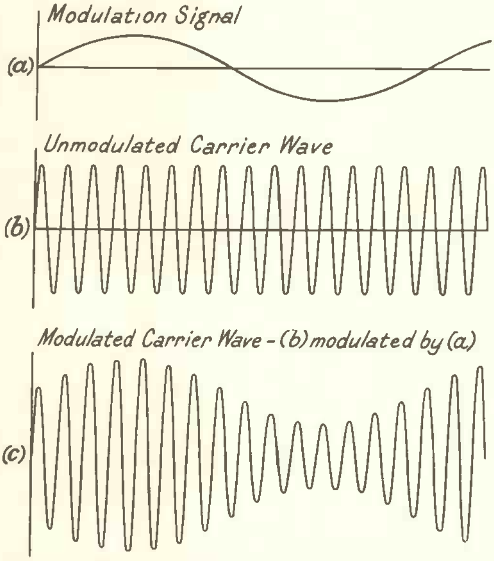


Fig. 1.—TYPICAL GRAPH OF A CARRIER-WAVE. *a* shows the audio-frequency signal of a pure sine wave form; *b* shows the carrier-wave before modulation; and *c* after modulation. *a*, *b* and *c* are not drawn to same amplitude scale.

Two Main Processes

Most readers are aware that two main processes are necessary to the production of a signal at a broadcasting station, viz., the generation process, when the carrier wave of the station is generated, and the modulation process, when the speech and music from the studio is super-imposed on the carrier wave.

Suppose that we tune a receiver to the local station during an interval in the programme. Apart from incidental noises, only a faint rushing sound is heard unless the receiver is made to oscillate, when a whistling noise is heard, the pitch varying with the tuning condenser adjustment. The faint rushing noise is due to the carrier wave, which is normally a pure sine wave such as we have already considered. The whistling noises we shall discuss later. The frequency of the sine wave carrier is, as we know, of the order of several hundred thousand cycles per second, or even greater.

Audio - Frequency Signal

Suppose now that a note is played in the studio and that it produces a pure sine wave signal in the amplifier at the broadcasting station. The modulator system of the transmitter superimposes this electrical signal, corresponding to the note from the studio and called the AUDIO FREQUENCY SIGNAL, on the carrier signal. The superimposition is not just that of introducing the two signals — carrier and audio-frequency note—into the aerial circuit, but is such that the carrier-wave ***maximum*** amplitude is no longer steady, but varies in a manner which corresponds *exactly* with the audio-frequency signal.

Modulation

Fig. 1 shows a typical graph of a carrier-wave before (*b*) and after (*c*) modulation by an audio-frequency signal of a pure sine wave form (*a*). In Fig. 2 is shown the effect of modulating a pure sine wave carrier wave with a note whose form is not a simple sine wave, but the complex form

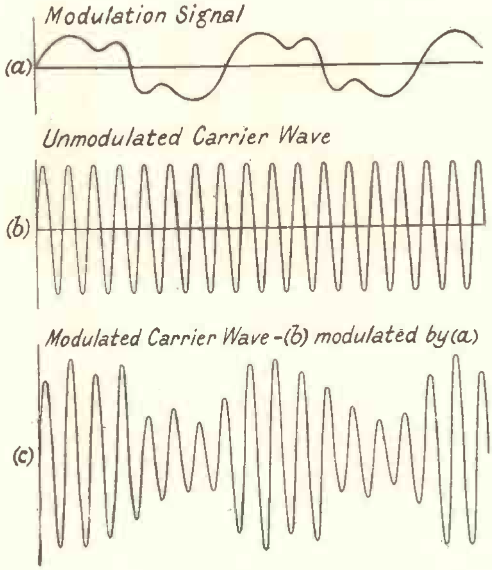


Fig. 2.—EFFECT OF MODULATING A PURE SINE WAVE.

Note that *a*, *b* and *c* are not drawn to the same amplitude scale.

shown at (*a*). Those readers acquainted with the use of the cathode-ray oscillograph will know that it is possible to study the form of carrier-wave signals and their modulation with this invaluable instrument, and complex wave forms, similar to that in Fig. 2, may be photographed for purposes of careful analysis.

Function of the Detector Valve

The function of the detector valve is to reverse the modulation process of the transmitting equipment. That is to say, the detector stage separates the audio-frequency signal from the carrier-wave, and passes it on to the audio-frequency amplifying stages of the receiver, where it is finally fed to the loud speaker for conversion into a sound-wave signal.

We cannot consider, in the short space we have available here, the analytical aspect of detector action. The preliminary mathematics leading up to an explanation of such an analysis would require a volume of its own of the size of COMPLETE WIRELESS! We shall, however, consider the matter from the graphical point of view, and shall discuss typical cases, differentiating between the various methods of detection in everyday use.

Process of Detection

The process of detection is, strictly speaking, a form of amplification in which wave distortion occurs. The type and extent of the distortion determines the effectiveness of the detecting action. Let us, therefore, examine the action of a three-electrode valve, under various operating conditions, when it is supplied with both modulated and unmodulated signals from a signal source such as an aerial. We know that in a tuned circuit a voltage is built up across the tuning coil when a signal is being received, and that the voltage available across the ends of the coil is many times the actual input signal voltage. In fact, the input-signal voltage is magnified by the coil magnification factor.

In Section XI we considered the effect of making small *permanent* changes in grid and anode voltages in a three-electrode valve circuit, and we observed the results of these changes, and from them we defined the three fundamental valve parameters.

Connecting a Tuned Circuit to a Three-electrode Valve

Suppose now that we connect a tuned circuit to a three-electrode valve in the manner shown by Fig. 3. In this circuit L_1 is a small coupling coil so placed that when it is connected to a source of signals the signal is transferred, by a mutual induction effect, to the tuned circuit comprising L_2 and C. The signal voltage, magnified by the coil magnification factor, is available across the terminals marked *p* and *q*.

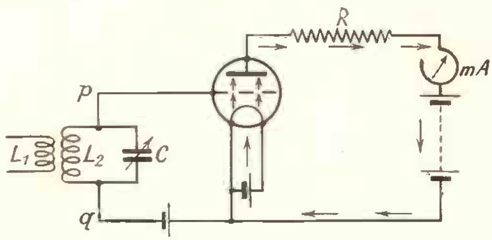


Fig. 3.—A TUNED CIRCUIT CONNECTED TO A THREE-ELECTRODE VALVE.

Difference of Potential

We will suppose that the resistance R has a value of 10,000 ohms, that the H.T. battery voltage is 120 volts, and that the anode current, when no signal is being received, is 2 m.A. Now, the anode current passes through R—the electron stream composing the current is in the direction shown by the arrows—and hence, by Ohm's law, there will be a difference of potential between the ends of the resistance. Expressing the current in amperes, we have :—

Potential difference (P.D.) across R =

$$\frac{2}{1,000} \times 10,000 \text{ volts.}$$

i.e., P.D. across R = 20 volts.

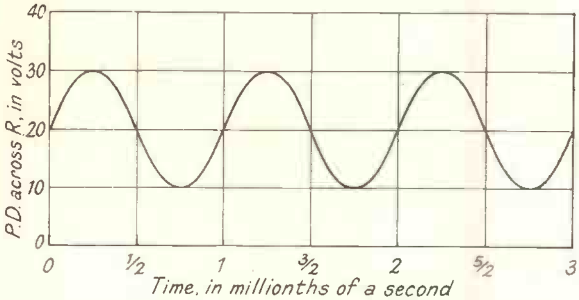


Fig. 4.—Graph showing how Potential Difference Varies with Alternations of the Incoming Signal.

Hence the actual voltage at the anode of the valve is the H.T. battery voltage of 120 volts *minus* the P.D. of 20 volts across R, or 100 volts. Suppose that the valve is biased so that any small *increase* in grid voltage produces the same *change* in anode current as a similar *decrease* in grid voltage. (The change in anode current will, of course, be positive or negative according to whether the grid voltage is made less or more negative.)

What happens when Unmodulated Signals are being Received

Suppose also that the tuned circuit is receiving unmodulated signals—*i.e.*, pure sine wave signals—whose frequency is 10^6 cycles per second (wavelength = 300 metres), and let the signal be such that the maximum amplitude of the voltage across the tuned circuit is 1 volt. That is to say, a sine wave voltage, of maximum amplitude 1 volt, and of frequency 10^6 cycles per second, is available between p and q.

Instantaneous Amplitude at Various Instants

The instantaneous amplitude at various instants can be found, as was done in Sections II and III of this series, and the following table shows the instantaneous amplitude at various instants during one complete cycle of alternation of the signal. The wave performs one complete cycle in one-millionth of a second, and the instants given in the first column are millionths of a second from the commencement of the cycle.

The complete sequence is repeated continually, and occurs a million times in each second. The + sign indicates that the terminal p is positive with respect to q, and the − sign indicates the alternation of the signal when p is negative with respect to q. As in previous cases, it will be seen that the signal is positive for one-half of its cycle and negative for the following half cycle.

Time.	Amplitude in Volts.
0	0
$\frac{1}{12}$	+ 0·5
$\frac{1}{8}$	+ 0·7
$\frac{1}{6}$	+ 0·9
$\frac{1}{4}$	+ 1·0
$\frac{1}{3}$	+ 0·9
$\frac{3}{8}$	+ 0·7
$\frac{5}{12}$	+ 0·5
$\frac{1}{2}$	0
$\frac{7}{12}$	− 0·5
$\frac{5}{8}$	− 0·7
$\frac{2}{3}$	− 0·9
$\frac{3}{4}$	− 1·0
$\frac{5}{6}$	− 0·9
$\frac{7}{8}$	− 0·7
$\frac{11}{12}$	− 0·5
1	0

Varying Number of Electrons

The electron stream from the filament is affected by this variation of grid potential, and a varying number of electrons now passes through R instead of a steady number as previously. (We saw in Section XI that as the grid voltage was varied the electron stream varied; making the grid less negative increased the electron stream, and *vice versâ*.)

Anode Current Variations

This varying electron flow is generally spoken of as a varying current through R. Note, however, that the direction of the electrons is always in the direction of the arrows of Fig. 3, only the rate of flow of the electrons varies. Suppose that the actual anode current variations are as shown by the following table :—

Signal Voltage on Grid in Volts.	Anode Current in Milliamps.
0	2·0
+ 0·5	2·5
+ 0·7	2·7
+ 0·9	2·9
+ 1·0	3·0
+ 0·9	2·9
+ 0·7	2·7
+ 0·5	2·5
0	2·0
− 0·5	1·5
− 0·7	1·3
− 0·9	1·1
− 1·0	1·0
− 0·9	1·1
− 0·7	1·3
− 0·5	1·5
0	2·0

Consider the effect of this varying current. We know, from Ohm's law, that a P.D. exists across the ends of a resistance carrying a current, and hence the P.D. across R will vary when a signal is being received, and the variations depend on the variations of the incoming signal. We have seen that the P.D. across R is 20 volts when the anode current is 2 m.A., and, working out the other values of P.D. corresponding to the current values given by the preceding table, we can draw the graph of Fig. 4 showing how the P.D. varies with the alternations of the incoming signal—*i.e.*, with time.

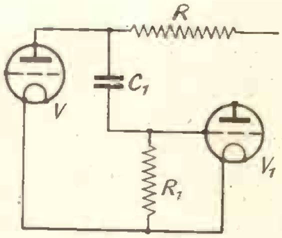


Fig. 5.—Circuit showing how the Alternating Voltage across the Ends of the Resistance R can be Used.

Sine Wave Alternating Voltage

Inspection of this graph shows that it is not quite a sine wave alternating voltage. The amplitude is not alternately positive and negative, but varies about a mean level of 20 volts. We can, however, look upon the voltage as being composed of a steady voltage of 20 volts together with a sine wave alternating voltage, of maximum amplitude 10 volts, and this is the usual practice when we are considering the action of the valve. The sine wave component of the anode voltage is *exactly* similar in wave form to the grid input signal voltage, and the action of the valve has resulted in an amplification of ten times, provided that we can utilise the alternating voltage across the ends of the resistance R.

It is well known that we can usefully employ this voltage, and a circuit similar to that of Fig. 5 is used. The condenser C_1 prevents the H.T. battery from short-circuiting to the filament *viâ* the resistance R_1, but offers very small impedance to the alternating voltage, and hence the alternating voltage is available across R_1, which is virtually in parallel with R.

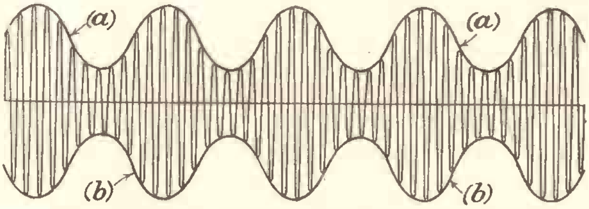


Fig. 6.—Curve showing the Audio-frequency Variations in the Carrier Amplitude.

That is to say, in our particular case, the 10-volts signal voltage is now available across R_1 for operating the second valve V_1. A similar process now ensues as the signal is transferred from the grid circuit to the anode circuit of V_1, and so on through subsequent stages of the instrument.

Tuned Anode Circuit

We have taken a simple case in which the anode circuit comprises a pure resistance. When a tuned circuit, a choke (H.F. or L.F.), a transformer (H.F. or L.F.), or any combination of these is employed, the action is more complex but the result is similar, viz., an amplification of the initial grid voltage and a preservation of the wave form—the latter within certain limits which we cannot discuss now.

Result would be Similar with a Modulated Wave

The signal we have considered was an unmodulated carrier-wave signal. Had we been dealing with a modulated wave of the form of Figs. 1 and 2 the valve would have dealt with this in a similar manner, and would have amplified the signal without changing the wave form. If we had placed a telephone in the anode circuit, would it have responded to the modulation ? In other words, would the valve have acted as a detector and have "sifted" the carrier and modulation components of the signal ? We can answer "No" immediately, because we have stated earlier that detection is a form of amplification in which wave distortion occurs, and this valve does not cause distortion ; in fact, the wave form is preserved. We can arrive at the same answer by a more explanatory reasoning process, however.

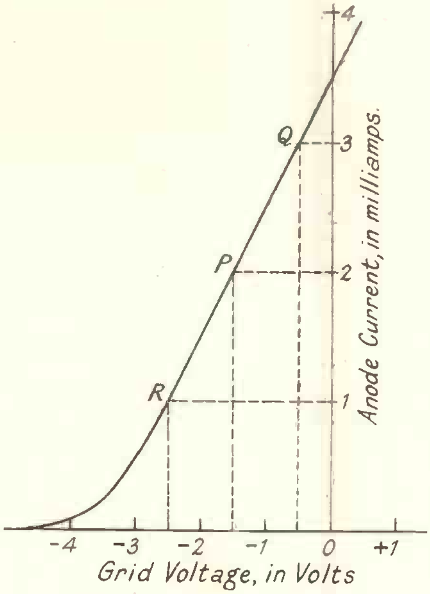


Fig. 7.—GRID VOLTAGE-ANODE CURRENT CURVE.

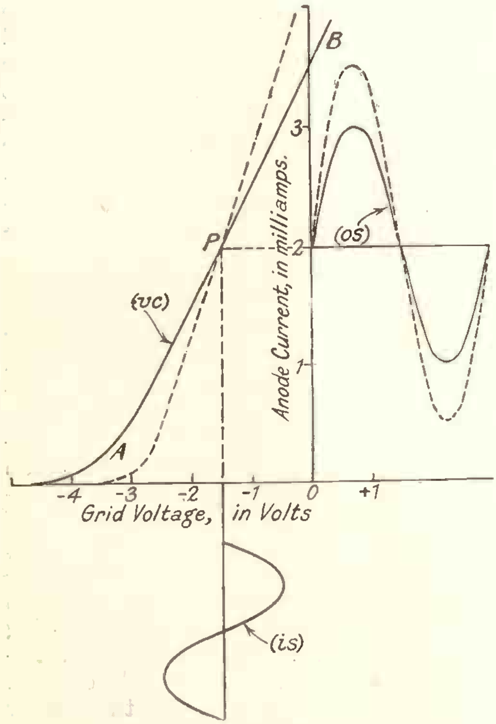


Fig. 8.—ANODE CURRENT CURVE FOR ONE COMPLETE CYCLE OF THE SIGNAL.

The Envelope of the Modulated Wave

Firstly, a telephone cannot respond to current variations at a frequency of the order of 10^6 cycles per second, and hence cannot respond to the carrier wave signal. Thus, had we placed the telephone in the anode circuit in the case of the reception of the unmodulated wave, no audible note would have been observed. In the case of the modulated signal, we can draw a curve showing the audio-frequency variations in the carrier amplitude, and this has been done in Fig. 6. This curve is called the ENVELOPE of the modulated wave. It will be seen that the slow (*i.e.*, audio-frequency) variations in carrier amplitude are shown by means of two curves, marked (*a*) and (*b*), exactly similar, except that they oppose each other—one is the inverse of the other.

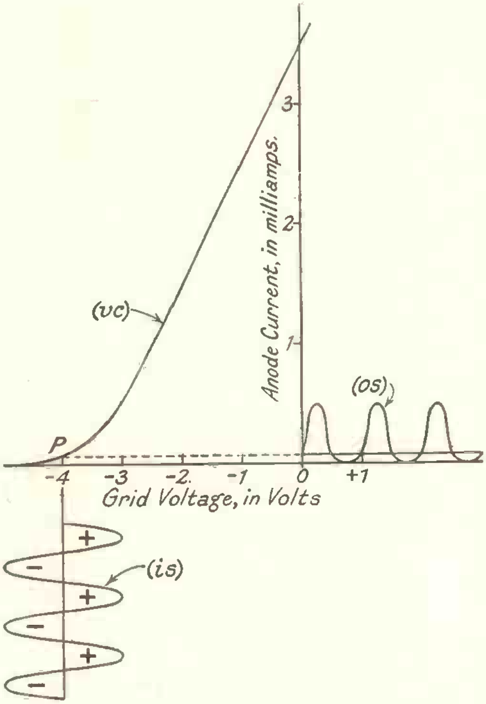


Fig. 9.—CURVE RESULTING WHEN THE OPERATING POINT OF THE VALVE IS MOVED, SO THAT ONE HALF OF THE SIGNAL CURVE IS SUPPRESSED.

We have just seen that a telephone does not respond to the rapid (radio-frequency) variations of the incoming signal, but it will, however, respond to audio-frequency variations of current such as are represented by curve (*a*) or curve (*b*). The effect of both (*a*) and (*b*) together is, however, a cancellation of each. Thus, whereas a telephone would respond to the audio-frequency variations of one curve alone, there is no response when both curves contribute to the total variation.

How Wave Distortion can Occur

From the foregoing it is evident that if we can suppress, or partially suppress, one of the curves (*a*) or (*b*) of Fig. 6, we shall distort the incoming wave and so "detect" the modulation. Let us interpret the amplifying action in terms of the characteristic curves of the valve, and from our examination of the curves it will be clear how wave distortion, resulting in detection, can occur.

Fig. 7 shows the grid voltage-anode-current curve for the valve we employed in the circuit of Fig. 3. The point P on the curve corresponds to a grid bias of $-1\frac{1}{2}$ volts and an anode voltage of 100 volts; we see that the anode current for these values is 2 mA.

The points Q and R represent the conditions when the signal voltage on the grid reaches its maximum positive and maximum negative amplitudes, and the corresponding anode current values are 3 mA. and 1 mA. On the same graph we can draw the sine wave voltage applied to the grid of the valve, and by combining the two curves—the characteristic curve and the signal curve—we can draw the anode current curve when the signal is passing. This has been done in Fig. 8 for one complete cycle of the signal. In Fig. 8 the three curves are labelled (*vc*), (*is*), and (*os*), representing the valve characteristic (*vc*), the input signal curve (*is*), and the output signal curve (*os*).

The Operating Point

The point P in the figure is usually termed the OPERATING POINT for the valve, and is the point on the curve which represents the no-signal condition. Curve (*os*) is obtained by finding the points corresponding to curve (*is*) by a process akin to reflection in curve (*vc*). If we change the slope of the straight portion AB of (*vc*) we shall obtain a new curve (*os*), and this is shown by the dotted lines in the figure. Changing the slope of the portion AB of (*vc*) has had the effect of changing the maximum amplitude of the alternating component of the anode current. The steeper the slope of AB the greater the maximum amplitude of (*os*) for a given signal curve (*is*), and *vice versâ*.

When an Amplifying Valve is most Effective

Now we saw, in Section XI, that the slope of AB is actually the slope, or mutual conductance, of the valve, and hence we can say that the greater the slope, or mutual conductance, of the valve, the greater the amplification of the input signal. *Thus an amplifying valve is most effective—other things being equal—when the slope, or mutual conductance of the valve is a maximum.* In the case of S.G. valves the presence of the fourth electrode—the screening grid—does not affect the foregoing explanation, and the same ruling applies—*i.e.*, the greater the slope, the more effective the valve as an amplifier.

Suppose now that the portion AB of the curve is not straight or nearly straight. That is to say, suppose that we move the operating point of the valve so that one half, or as much of one half as possible, of the signal curve (*is*) is suppressed. This condition is represented by the curves of Fig. 9. It will be seen that the half cycles of (*os*) corresponding to the negative half cycles of (*is*) are almost completely suppressed. If now the carrier wave represented by (*is*) be modulated, only one of the two curves (*a*) and (*b*) of Fig. 6 are present in (*os*), the other being suppressed with the half cycles of (*os*) corresponding to the negative half cycles of (*is*). A telephone would now respond to the modulation frequencies. This is illustrated by Fig. 10.

Various Methods of Detection

When this condition obtains, or partially obtains, " detection " occurs, and the modulation frequencies can then be converted into sound waves with the aid of a telephone or loud speaker. Detection conditions obtain under several circumstances and this gives rise to various methods of detection, the chief of which may be enumerated thus :—

(1) Anode bend detection.
(2) Leaky grid detection.
(3) Power grid detection.
(4) Diode detection.

We shall devote the next section to a detailed examination of the processes involved in these four methods, and to considering certain factors influencing the practical problem of detector circuit design.

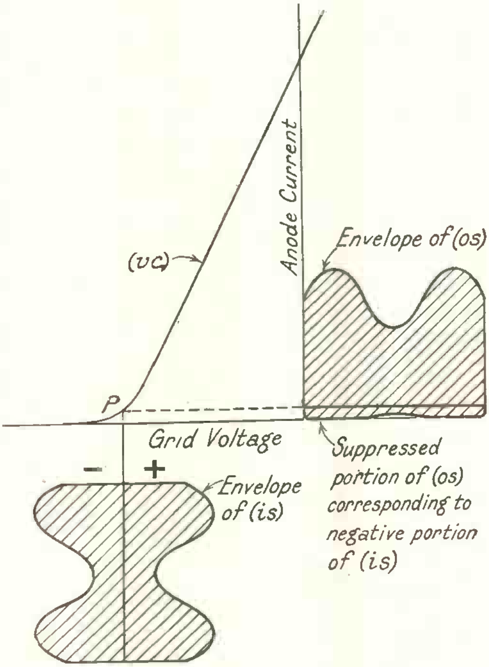


Fig. 10.—Curve showing the Result of Modulating the Carrier Wave represented by (is).

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XVIII—A GENERAL SURVEY OF A RECEIVING CIRCUIT

UP to the present we have been studying separately every part of the wireless receiving circuit. We have also considered the general principles underlying wireless transmission. As you have seen, the whole thing is based on the theory of electricity and magnetism. You will realise now why I did not start on the receiving circuit straight away, but gave a good deal of the preliminary background. In my opinion if a serious study of wireless is contemplated this preliminary work is essential.

Let us proceed with our summing up of the previous work.

How the Modulated Electro-magnetic Wave is Produced

A performer in the studio, be he a singer, a lecturer or a musician, creates a series of *sound waves* which cause the carbon diaphragm of the microphone to vibrate. The vibrations of the microphone diaphragm alter the resistance of the instrument so that with the variation in resistance of the microphone circuit, the current flowing in it also varies. In this manner for every sound emitted there is a corresponding electrical impulse. The currents thus obtained in the microphone circuit are amplified and are brought to the transmitter. The latter is already feeding the aerial with a uniform and regular alternating current which is called the *carrier current*, and when the *microphone current* makes itself felt the two currents, the carrier current and the microphone current, combine into a *modulated current*. The modulated aerial current is now bearing the characteristics of sound waves produced in the studio. The flow of modulated current in the aerial results in the radiation of a modulated *electro-magnetic wave* in all directions.

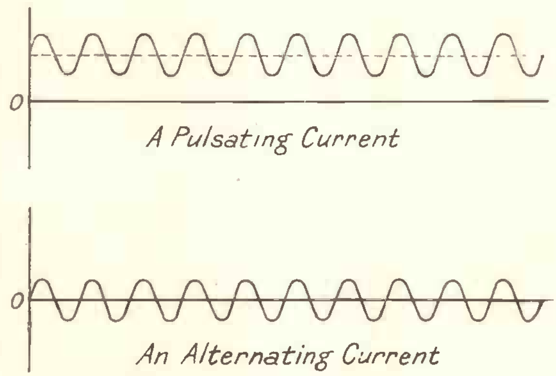


Fig. 1.—THIS SHOWS THE DIFFERENCE BETWEEN A PULSATING CURRENT, E.M.F. OR MAGNETIC FIELD AND AN ALTERNATING CURRENT, E.M.F., OR MAGNETIC FIELD.

The Sound Waves Control the Radiated Electro-magnetic Wave

Now, since it is the sound waves in the studio that are controlling the character of the currents in the microphone circuit, and it is the microphone currents that determine the character of the modulated currents and therefore of the modulated electro-magnetic waves, we can say that the sound waves in the studio control indirectly the radiated electro-magnetic wave.

Effect of Electro-magnetic Wave on Open and Frame Aerials

The modulated electro-magnetic wave spreads in space in all directions with the speed of light (186,000 miles per second) and affects every aerial it encounters. If it meets an outdoor open aerial it brings its electric field into action and causes electronic tides in the aerial-earth system, and if it meets a frame aerial its magnetic field comes into action. The lines of force of this magnetic field cut the conductors of the frame aerial winding and induce an E.M.F. in it.

High Frequency Oscillating Currents

In this manner electrical currents are produced in the receiving aerial, currents of the same nature as those flowing in the transmitting aerial. These currents are *high frequency oscillating* (alternating) *currents*. Now look at Fig. 5.

It is clear that as soon as a train of electro-magnetic modulated waves reaches our receiving aerial currents will be made to flow (an electronic tide will be caused) in our aerial-earth system C_1L_1.

Adjusting the Tuning Circuit

But there may be a large number of waves reaching the aerial from all sorts of broadcasting stations. For this reason it is necessary to adjust our *tuning circuit* for reception of the desired wavelength. Our tuning circuit is of the *acceptor* type, and this acceptor C_1L_1 represents the *primary of our aerial circuit*.

What the Variable Condenser Does

In order to bring the primary to the same electrical conditions as the transmitting aerial of the desired station, we vary the adjustment of the variable condenser C_1 till the frequency of current flowing in our primary aerial circuit is the same as the frequency of the current flowing in the transmitting aerial. Once this is done the acceptor circuit will offer an easy path to currents induced by the wave of the tuned (or resonant) frequency, and a difficult path to all other (undesirable) frequencies. The currents oscillating in the primary aerial circuit will cause a rapidly alternating magnetic field around the coil L_1. This magnetic field will spread out in space and will contract upon the coil L_1 as the current within the coil grows and collapses. The lines of force of this magnetic field rapidly moving in space will cut at right angles the conductors in the coil L_2 and will induce in it currents of the same frequency as those flowing in the primary aerial circuit.

The Secondary Aerial Circuit

The circuit C_2L_2 forms therefore the *secondary aerial circuit*. It is clear that if the current induced by the primary in the secondary coil is to flow at its maximum intensity at every instant it is necessary to adjust the secondary circuit so that it offers the least possible opposition to the flow of current at this particular frequency. The condenser C_2 comes into play, and the distance between the primary and the secondary coils is also adjusted for best results when plug-in coils are used.

In this manner if we have an instantaneous E.M.F. *e* across the coil L_1, we shall have the same E.M.F. *e* across the secondary coil and therefore across the grid circuit of the first valve, which is a three electrode H.F. valve. (I have taken this old-fashioned circuit consisting of three electrode valves on purpose, as it simplifies the diagram enormously. You will also notice that I have introduced on purpose a large variety of intervalve coupling components so as to meet in our discussion every possible case.) Thus, provided that there are no losses of energy in the transfer of the E.M.F. from L_1 to L_2 we shall have across the grid of the first valve the same E.M.F. *e*. This E.M.F. is an alternating one.

Direct Pulsating Current

As we already know, every potential variation on the grid of the valve is faithfully reflected in the anode current, so that since our potential across the grid is an alternating one and since the valve will allow the current to flow in one direction only from the filament to the anode, we shall have a *direct pulsating current* flowing in the H.F. choke L_4. This direct pulsating current will now grow in value, now diminish so that there will be a magnetic field around the choke, which will grow, *i.e.*, spread in space and retire upon the coil. Thus, it will cut the conductors of the coil now in one direction, while spreading, now in the opposite direction, while contracting.

Back E.M.F. Across the Choke

Therefore, although the current flowing through the choke is a direct pulsating current, the back E.M.F. induced by the field in the choke will be an alternating one. As you see a direct pulsating current flowing through a choke has upon it, from the self-induction point of view, the same effect as an alternating current, and this is because the field cuts the conductors of the choke in opposite directions.

The back E.M.F. across the choke is much larger than the E.M.F. *e* applied to the grid of the first valve. The reason for this is that it is caused by a large current flowing through the choke.

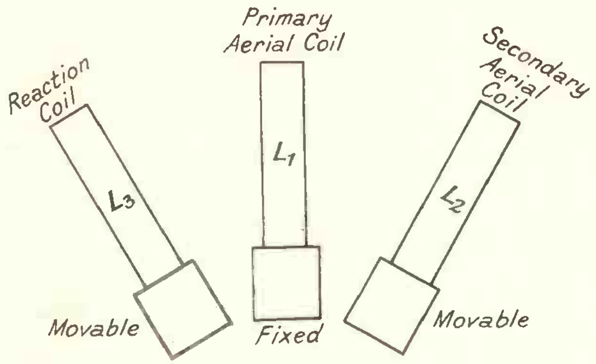


Fig. 2.—Showing Method of Coupling of Reaction Coil.

E.M.F. Across Anode Circuit is applied simultaneously across Grid Circuit of next Valve

If you remember, when we have re-drawn the circuit with a separate H.T. battery for each valve we have seen clearly how an E.M.F. developed across the anode circuit is at the same time applied across the grid circuit of the next valve. Therefore, the back E.M.F. E_1 is automatically applied across the grid circuit of the second valve V_2. From the diagram Fig. 5 you can see why the condenser C_3 is placed where it is. If there were no condenser we should have a closed circuit across the H.T. battery, *via* the filament connecting leads, the grid leak of valve V_2, and the choke L_4.

Direct Pulsating Current Flowing through Tuned Choke

The alternating E.M.F. E_1 applied to the grid of the valve V_2 results in a direct pulsating current flowing through the tuned choke L_5 (tuned anode), and once more the back E.M.F. developed by the choke is an alternating one. The variable condenser across the choke serves for tuning the circuit so that it offers the least opposition to the selected frequency. This arrangement is more efficient than that of the anode of valve V_1. Again, owing to the amplification of the valve itself, the back E.M.F. E_2 is larger than the E.M.F. E_1 applied to the grid. E_2 is automatically applied to the grid of the valve V_3, which is *the detector valve*.

The Method of Detection

The method of detection is the leaky grid method, the grid leak instead of being across the coupling condenser is in series with it. The anode current is made to flow from the anode of the valve V_3 *via* the reaction coil L_3, and from there through the primary of the low-frequency intervalve transformer and so back to the H.T. battery. The reaction coil develops a high-frequency back E.M.F. E_3, and induces this E.M.F. electro-magnetically into the primary aerial coil to which it is coupled (see Fig. 2).

How the Reaction Coil Increases Amplification

From now on, the primary aerial coil will have two E.M.F.'s in it, the E.M.F. *e* induced by the passing electro-magnetic wave and the E.M.F. E_3 induced by the reaction coil. If the reaction coil is wound the right way round these two E.M.F.'s will be in step and will add up to form a resultant and larger E.M.F. This resultant E.M.F. will be induced in the secondary aerial circuit, so that we shall have across the grid of the first valve a much larger E.M.F. than *e*. This means that the effect will be amplified all round, and thus we shall obtain across the primary of the transformer an E.M.F. larger than E_3, namely E_4.

Separation of H.F. Components from L.F. Components

It is at this point that the separation of

(P24).

the high frequency component from the low-frequency component takes place. The high frequency pulsating current flowing in the anode circuit of the valve V_3 meets with such an opposition in the primary winding of the transformer that it has to go along the line of least "resistance," namely, *via* the by-pass condenser C_6. The high frequency current thus traverses the reaction coil and passes on, *via* the by-pass condenser to the H.T. battery and so on to earth. It charges up the condenser C_5, which in discharging its cumulative charges through the primary causes low frequency currents to flow through it. This current causes a low frequency magnetic field to grow and retract around the primary coil and, since the lines of force of this field are cutting the conductors of the secondary transformer coil in opposite directions, *an alternating E.M.F.* is induced in the secondary.

The transformer in question being a step up transformer, the secondary coil has more turns than the primary coil, and for this reason the E.M.F. E_5 developed across the secondary coil and therefore across the grid circuit of the valve V_4 is a much larger E.M.F. than E_4, and is of an alternating nature.

This E.M.F. E_5 across the grid of the valve V_4 causes a large direct pulsating current in the anode circuit of the valve V_4, a current which traverses the anode resistance R and causes in it a variable voltage drop E_6.

The variable voltage drop across the resistance caused by a large current will be much greater than the E.M.F. E_5 applied to the grid of the valve V_4. Thus E_6 developed across the resistance and automatically applied across the grid circuit of the last valve is larger than E_5. The E.M.F. E_6 is a direct pulsating E.M.F.

The E.M.F. Applied Across the Loudspeaker Windings

Thus, we have a direct low frequency pulsating E.M.F. applied across the grid of the last valve, an E.M.F. which will result in a direct pulsating current in the anode circuit of the last valve V_5. This is the E.M.F. E_7 which is applied directly across the loud speaker windings.

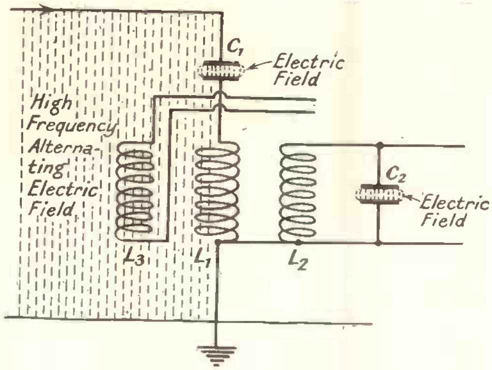


Fig. 3.—This shows the instant when the Charges are Swiftly establishing Themselves.

Under the influence of this E.M.F. E_7 a low frequency pulsating current will be made to flow through the loudspeaker windings, causing a low frequency magnetic field which will cause the loudspeaker diaphragm to vibrate with low frequency, *i.e.*, audible frequency, and thus cause sound waves of the same kind as those in the studio.

Condenser Across Loudspeaker Windings

You will notice how each valve sends out its own anode current towards the H.T. battery and how in the end five anode currents combine into one flow. The condenser across the loudspeaker is a matter of precaution and serves as a by-pass for any undesirable oscillating currents.

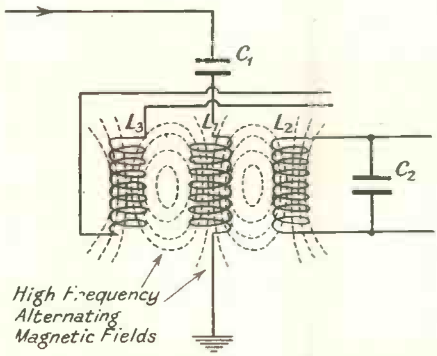


Fig. 4.—When a Discharge takes place the Magnetic Fields make their appearance, reaching their Maxima when the Currents reach their Maxima.

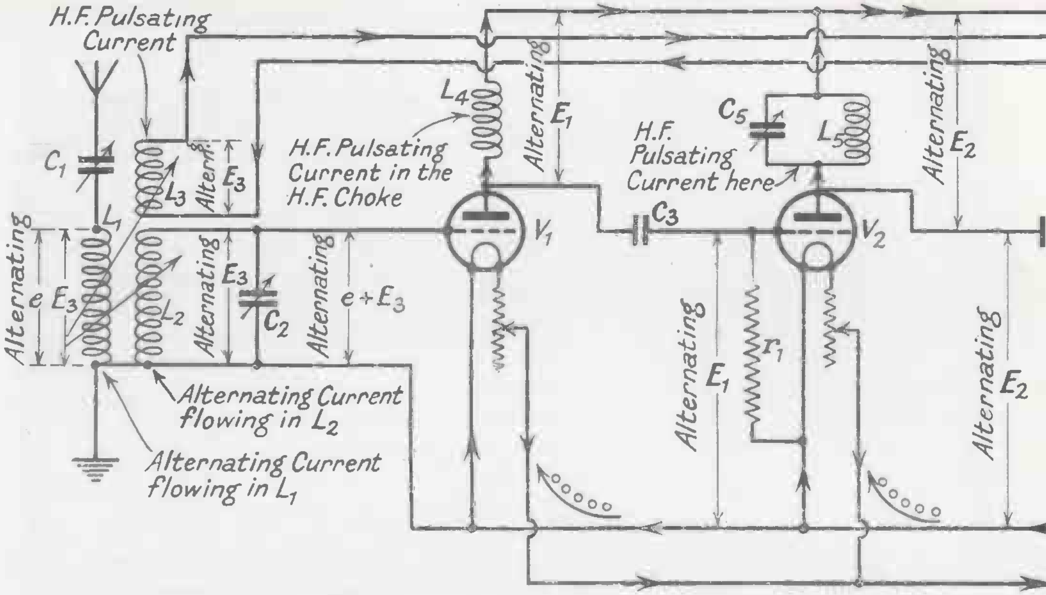


Fig. 5.—HERE CAN BE SEEN, STAGE BY STAG

As soon as a train of electro-magnetic modulated waves reaches the receiving aerial, currents will be r
is clearly described in this article.

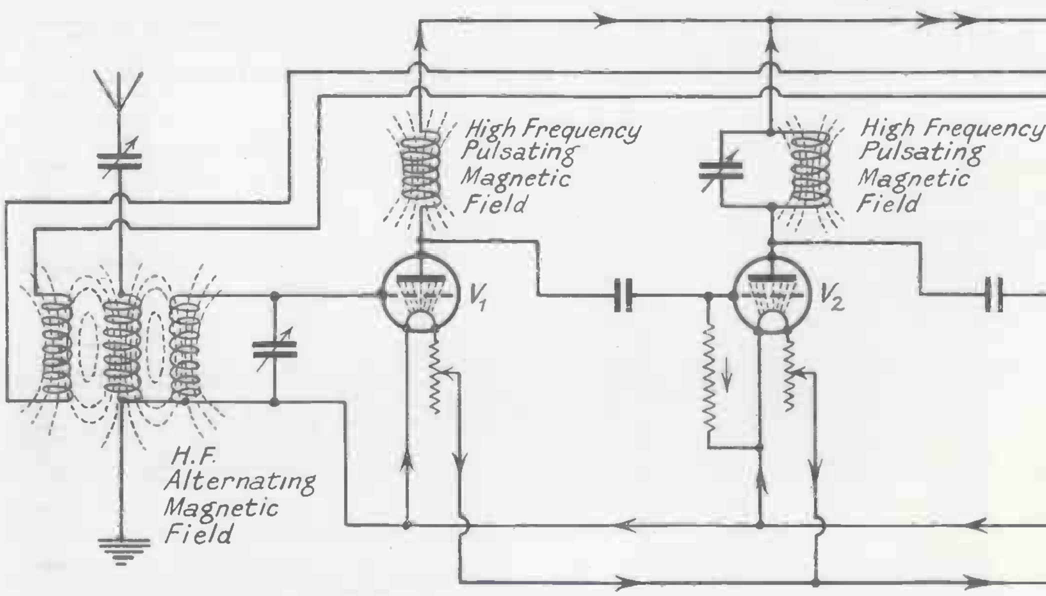
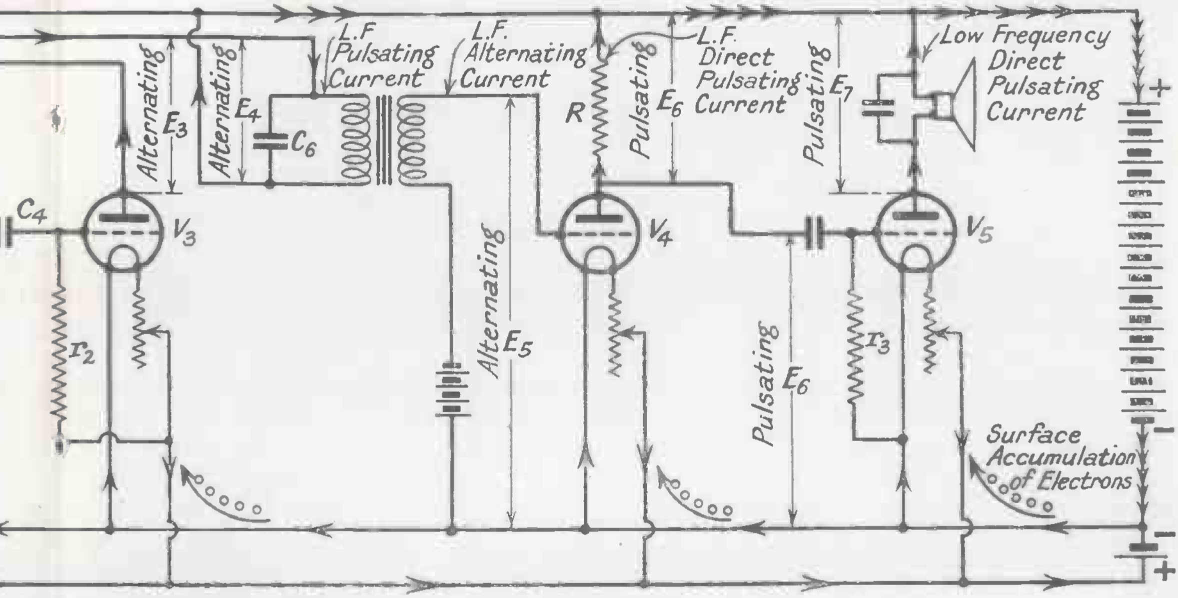
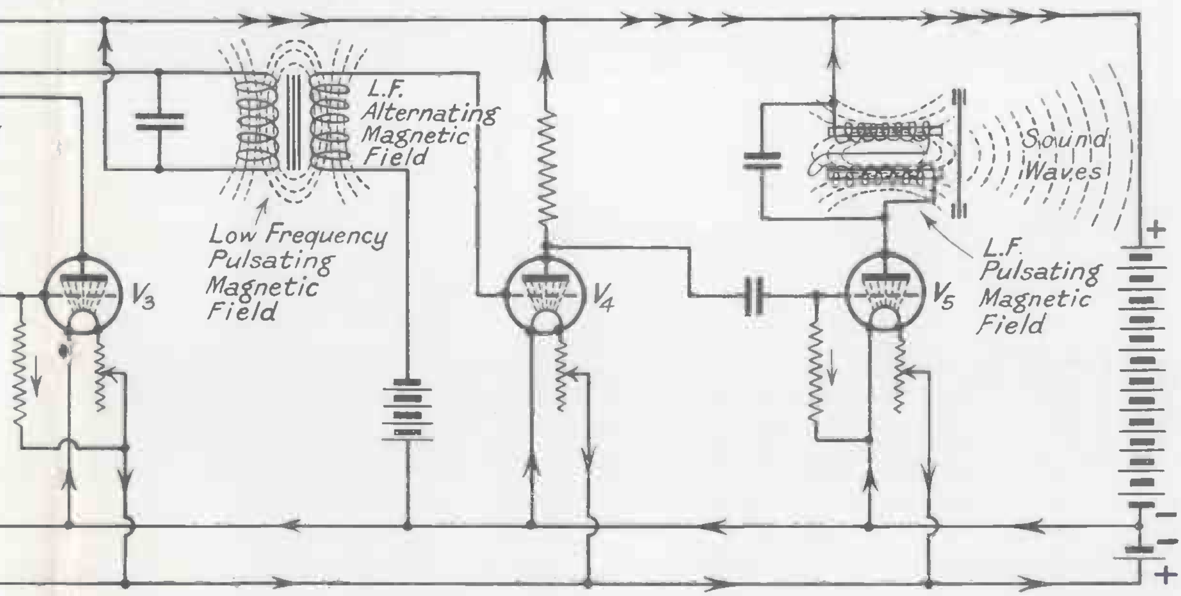


Fig. 6.—IN THIS INTERESTING DIAGRAM WI



E, THE CURRENTS THAT FLOW IN A WIRELESS RECEIVER.

made to flow (an electronic tide will be caused) in the aerial-earth system C_1L_1. What happens to these currents



E SEE ALL THE MAGNETIC FIELDS COLLECTED TOGETHER.

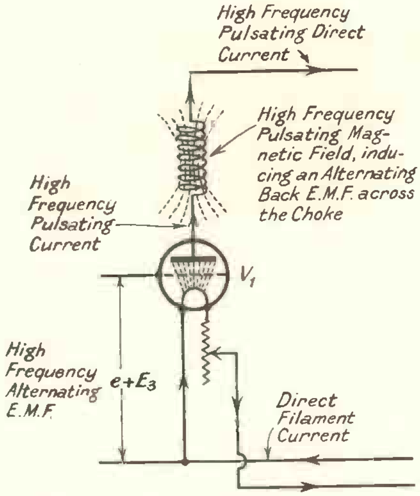


Fig. 7.—WHAT HAPPENS IN THE FIRST VALVE CIRCUIT.

In the first valve circuit we have a flow of electrons through the valve and in the anode circuit, and the anode current produces a high-frequency pulsating magnetic field which induces in the choke a high-frequency alternating back E.M.F.

Function of the Grid Leaks

The function of the grid leaks is to enable the accumulation of electrons on the grid to leak away slowly, but never fully. Thus the grids of the valves are being kept all the time within the permissible limits of potential variation. You may look upon a grid leak as a timing device for the electron leakage.

This is, briefly, what happens within the receiving set. It is clear that if the receiver is to work properly the sound characteristics of the electro-magnetic wave must be preserved through the whole number of stages.

Slightest Variation of Potential will cause Distortion

The slightest variation in potential in any stage and distortion will creep in, only to be multiplied from stage to stage. To begin with, every valve must be worked at its correct filament voltage (filament regulators are provided for each valve for the purpose of voltage regulation), its correct anode voltage and its correct grid bias. In practice we would not use one common H.T. lead for all valves but each valve would have its appropriate H.T. tapping. But the circuit in question is not meant for practical constructional purposes, but is given as an illustration of all possible cases of amplification.

How Stability is Ensured

You will notice that the primary and secondary aerial coils are joined by a common lead, so that the secondary coil is connected to earth. This ensures stability of the circuit, and easier control.

The Biassing Arrangements

The grid of the first valve is being kept at zero (earth) potential. The grid of the second valve obtains its bias through the grid leak from the negative side of the L.T. accumulator. The grid of the detector valve obtains its bias from the positive side of the L.T. accumulator, which is the usual practice with a detector valve. The grid of the fourth valve is given a bias from a separate grid bias battery, *via* the secondary winding of the transformer, and, finally, the grid of the last valves is biassed through a grid leak with the help of the negative side of the L.T. battery.

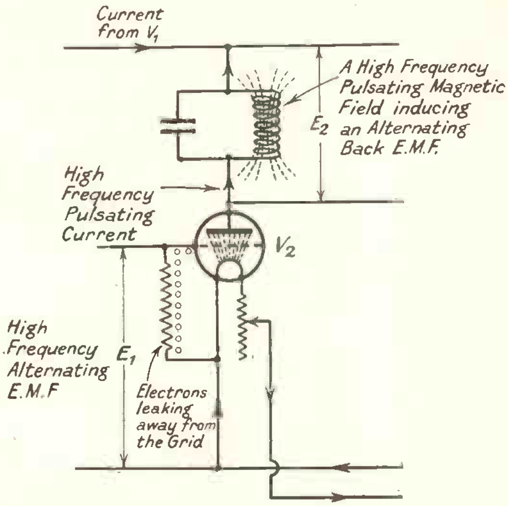


Fig. 8.—WHAT HAPPENS IN THE SECOND VALVE CIRCUIT.

In the case of V_2 we find again that there is a high-frequency pulsating magnetic field around the tuned choke. Once more this H.F. pulsating magnetic field produces an H.F. alternating back E.M.F.

Factors which Govern the Biassing of the Grids

The biassing of the grids depends on the design of the valves, and therefore on the recommendations made by the makers. If they recommend a grid bias greater than two volts either negative or positive, separate grid bias batteries have to be provided in each individual case.

The Physical Aspect of the Circuit

Now, let us examine the physical aspect of the circuit in question apart from the E.M.F.'s developed and currents flowing in each part of the circuit.

When the electro-magnetic wave reaches the aerial and the electric field establishes itself between the aerial and the earth, as it grows in intensity it drags electrons in the aerial circuit either towards the aerial or away from it, thus charging up the aerial-earth system. Thus in the first place electric fields make their appearance while all capacities are being charged up. Fig. 3 shows that instant when the charges are swiftly establishing themselves.

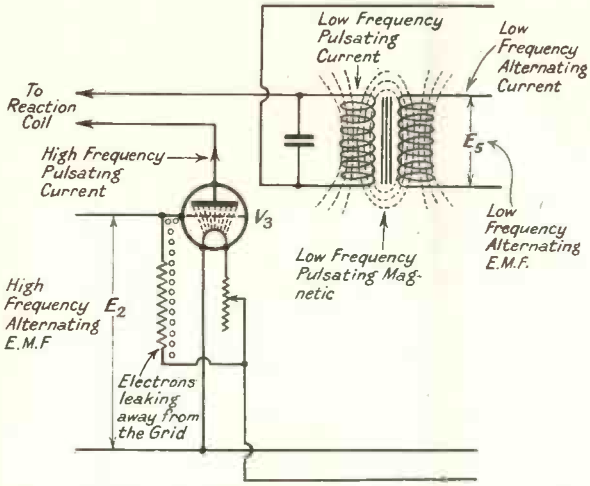


Fig. 9.—HERE WE SEE THE MAGNETIC FIELDS ESTABLISHED AROUND THE TRANSFORMER.

The low-frequency pulsating current in the primary produces a low-frequency pulsating magnetic field around the primary. This pulsating field, cutting the conductors of the secondary now in one direction, now in the opposite direction, induces in it a low-frequency alternating E.M.F.

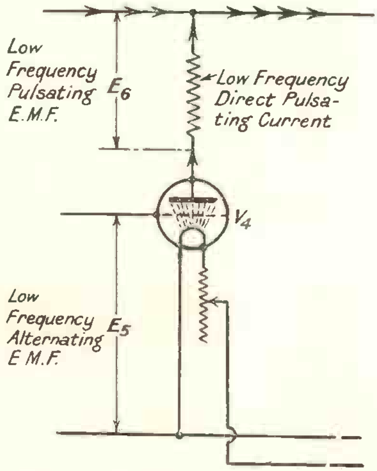


Fig. 10.—WHAT HAPPENS IN THE FOURTH VALVE CIRCUIT.

Here we see that the alternating E.M.F. applied to the grid of V_4 produces in the anode circuit of this valve a low-frequency pulsating current, which is causing a variable drop in voltage across the resistance. We have no magnetic field here, as the only thing a resistance can do is to dissipate some of the received energy in the form of heat.

Now, when a discharge takes place the magnetic fields make their appearance, reaching their maxima when the currents reach their maxima, and this is shown in Fig. 4.

What Happens in the First Valve Circuit

In the first valve circuit we have a flow of electrons through the valve and in the anode circuit, and the anode current produces a high frequency pulsating magnetic field which induces in the choke a high frequency alternating back E.M.F. (Fig. 7).

In the case of the valve V_2 we find again (Fig. 8) that there is a high-frequency pulsating magnetic field around the tuned choke. Once more this H.F. *pulsating* magnetic field produces an H.F. *alternating* back E.M.F.

Magnetic Fields around the Transformer

In Fig. 9 we see the magnetic fields established around the transformer. The low-frequency pulsating current in the primary produces a low-frequency pulsating magnetic field around the primary. This pulsating field cutting the conductors of the secondary now in one direction now in the opposite direction induces in it a low-frequency *alternating E.M.F.* This alternating E.M.F. applied to the grid of valve V_4 produces in the anode circuit of this valve a low-frequency pulsating current which is causing a variable drop in voltage across the resistance. We have no magnetic field here, as the only thing a

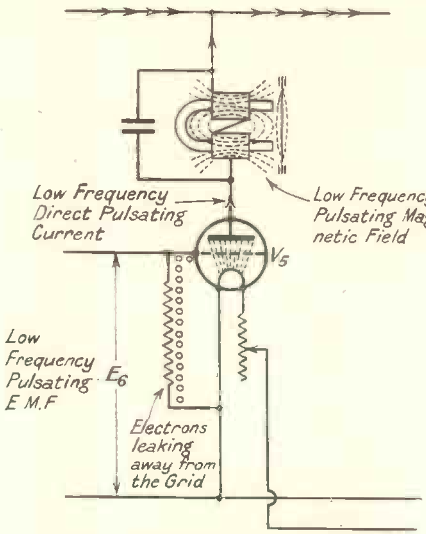


Fig. 11.—What Happens in the Last Stage of the Receiver.

Here we find once more a low-frequency pulsating magnetic field around the coils of the loud speaker. This magnetic field is the most important one, as it causes the vibration of the loud speaker diaphragm.

resistance can do is to dissipate some of the received energy in the form of heat.

This is shown in Fig. 10.

Last Stage of the Receiver

In Fig. 11, where we see the last stage of our receiver, we find once more a low frequency pulsating magnetic field around the coils of the loud speaker. This magnetic field is the most important one, as it causes the vibration of the loud speaker diaphragm.

In Fig. 6 all the magnetic fields are collected together.

A Wireless Receiver is by no means a dead affair!

There are many who think that a wireless receiver is a dead affair, "there is nothing going round that one can see," but those who know can see a good deal in their mind's eye. Electrons are swarming everywhere, in every conductor, collecting in crowds on condenser plates and valve grid leaks; jumping across a "void" inside a valve, stealing away quietly along a grid leak, collecting here, disappearing there and being everywhere at the same time. It is sufficient for electrons to accumulate on one plate of a condenser in order to repel other electrons from the opposite plate, and stretch lines of force of the electric field through the dielectric.

And when the glorious moment comes and everything is ready for a discharge, for a sudden rush inside some winding and a fight at every step with local electrons, what does it matter if one gets through or one is repelled and has to seek a by-pass condenser, the work is done and the signals are going through. And the jolly work of stirring up the ether as one rushes through a conductor, making magnetic fields appear and disappear so that they can stir up some somnolent electrons elsewhere!

Yes, there is plenty of life in a wireless receiver, plenty of movement if one looks for it. Electric and magnetic fields replace each other with lightning speed, and have to be watched that they do not spread too far, otherwise electrons will be roused and made to move with a speed far beyond that for which the component has been designed. Screening has to be effected and various components shielded from each other.

Electrons are wonderful Servants

Electrons are wonderful servants of those who understand them and provide the right kind of work for them, but woe betide the man who does not know them and starts playing about with a set. The electrons soon know who is in charge of them, and once they discover your weakness they take complete charge of the receiver, and, being practical jokers by nature, they will soon transform speech into a mush of sound.

QUESTIONS AND ANSWERS

Give in Outline a Summary of the Stages by which a Broadcast in a Studio is Converted into Sound in a Loud Speaker. (Assume that the Studio Microphone and the Loud Speaker are of the Moving Coil Type.)

(1) Sounds in the studio (*e.g.*, orchestral music, singing, or speaking) impinge on a microphone consisting of a light coil of wire suspended between the poles of a powerful electro-magnet.

(2) This causes the coil to vibrate in unison with the sound waves.

(3) The movement of the coil in the magnetic field sets up tiny currents in it. This current varies in strength and frequency in a manner which exactly corresponds with the sound waves.

(4) The currents are amplified in the usual way. In the meantime a regular (or carrier) alternating current is being supplied to the transmitting aerial from another source.

(5) The amplified microphone current is imposed on the carrier current, so that the transmitting aerial now receives a modulated current. This causes the transmitting aerial to radiate waves which are modulated in accordance with the sound reaching the microphone.

(6) These waves are picked up by the receiving aerial—which is connected to a circuit tuned to accept the carrier wave.

(7) The incoming waves set up varying high-frequency currents in the aerial circuit of the receiver.

(8) These, either directly or through a suitable coupling, vary the grid voltage of the first (H.F.) valve in the set. This causes an amplified varying current to flow in the plate circuit.

(9) This amplified current is rectified by the detector valve. This, in effect, smooths out the carrier wave and leaves only the L.F. component which was first imposed on it by the microphone.

(10) The rectified current is passed through a low-frequency transformer on to the grid of the low-frequency amplifying valve.

(11) This causes the plate current of the amplifying valve to vary in accordance with the variations in the microphone current in the studio.

(12) The plate current then passes into the speech coil of the loud speaker, and, by a reversal of the action of the studio microphone, sound waves are given out from the diaphragm.

What is the Function of a Grid Leak ?

The function of a grid leak is to enable the accumulation of electrons on the grid to leak away slowly, but never fully. Thus the grid of a valve is kept all the time within the permissible limits of potential variation.

How is Stability ensured in a Circuit ?

By joining the primary and secondary aerial coils to a common lead, so that the secondary coil is connected to earth.

ERECTING AN AERIAL

Fig. 1.—How to Join Rope to the Insulator.

The rope should be threaded through the insulator and the end bound in this manner. This is preferable to using knots, which are liable to come undone.

IN the following pages will be found some useful illustrations showing various stages in the erection of an aerial. A method of making a satisfactory fastening to a wall or chimney stack is shown in Figs. 2 to 5, while other photographs show approved methods of fastening the wire and rope to the insulators.

Fig. 2.—How to "Plug" a Wall to Hold the Aerial Fixing.

The tool necessary to make a hole suitable for a plug is called a "jumper," and can be made from a piece of gas barrel, at one end of which teeth are filed.

Fig. 8 shows diagrammatically a complete aerial installation, together with details relating to the "lead-in."

Wire to Use

A good quality copper wire should be used. The wire should be stranded and each strand separately enamelled. Convenient sizes to use are 3/18 S.W.G. and 7/22 S.W.G Phosphor bronze wire is sometimes used, as it is more able to withstand atmospheric erosion.

Fig. 3.—How to Make the Hole.

Place the "jumper" with the teeth against the wall and tap it with a hammer. Turn the "jumper" and give a few more taps, keeping turning and tapping until a hole of sufficient depth is produced.

Fig. 4.—Inserting the Plug.

A wooden plug is now inserted in the hole so that it can be pushed in flush to the wall.

Fig. 5.—Splitting the Plug with a Chisel.

The plug is now split down the centre with a chisel. A wedge is placed in the cut and driven home with a hammer, thus expanding the plug and compressing the wood tightly into the brick.

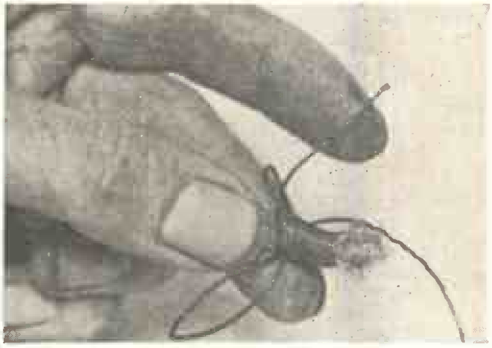


Fig. 6.—Whipping the Ends of a Rope.

About ½ inch of the end of the rope should be tightly wrapped round with twine in the manner shown.

Fig. 7.—How the Insulators should be Linked Up.

At least three insulators should be used at each end of an aerial, and they should be placed about 1 foot apart. This also shows the method of joining the aerial wire to the insulators.

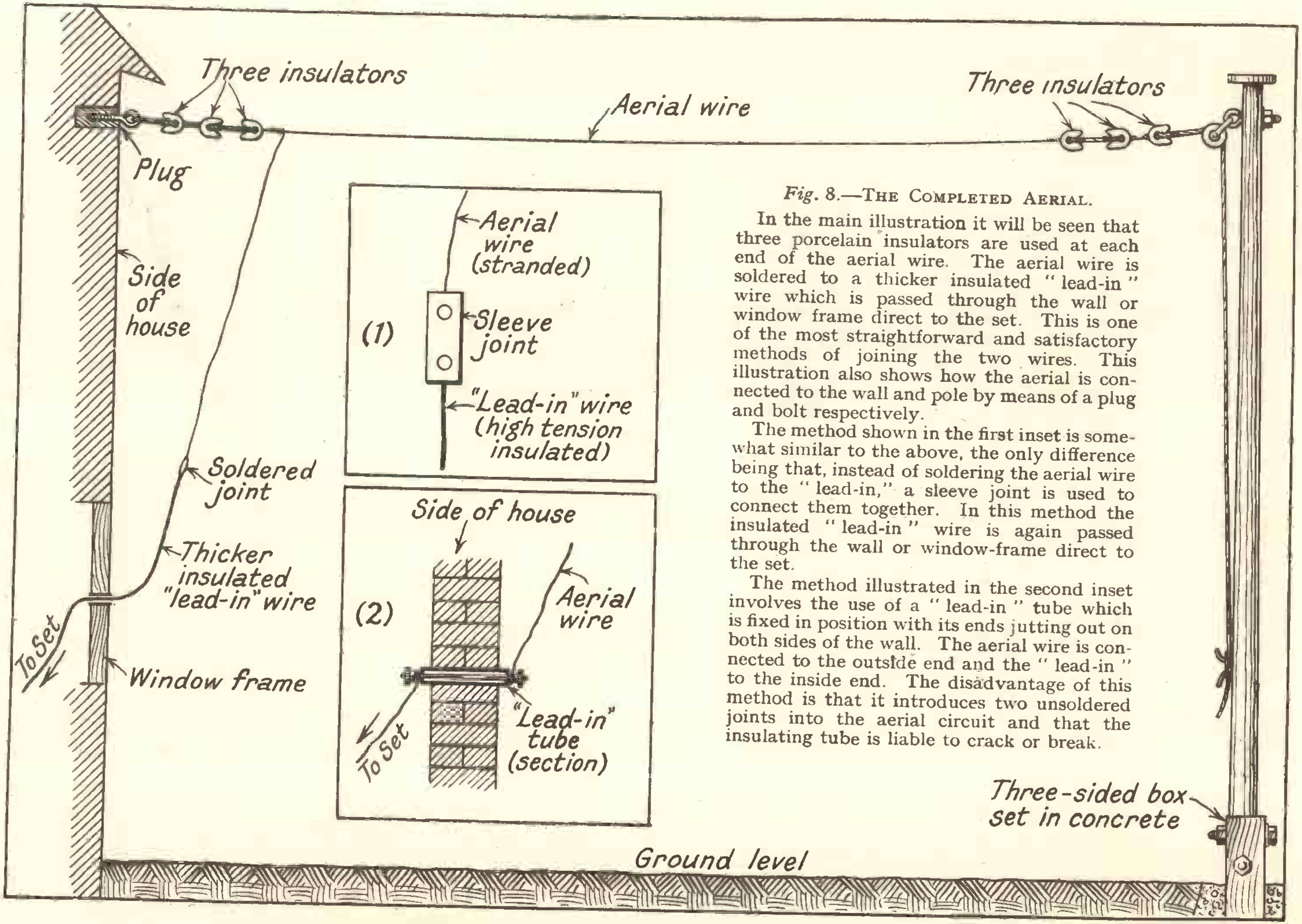


Fig. 8.—The Completed Aerial.

In the main illustration it will be seen that three porcelain insulators are used at each end of the aerial wire. The aerial wire is soldered to a thicker insulated "lead-in" wire which is passed through the wall or window frame direct to the set. This is one of the most straightforward and satisfactory methods of joining the two wires. This illustration also shows how the aerial is connected to the wall and pole by means of a plug and bolt respectively.

The method shown in the first inset is somewhat similar to the above, the only difference being that, instead of soldering the aerial wire to the "lead-in," a sleeve joint is used to connect them together. In this method the insulated "lead-in" wire is again passed through the wall or window-frame direct to the set.

The method illustrated in the second inset involves the use of a "lead-in" tube which is fixed in position with its ends jutting out on both sides of the wall. The aerial wire is connected to the outside end and the "lead-in" to the inside end. The disadvantage of this method is that it introduces two unsoldered joints into the aerial circuit and that the insulating tube is liable to crack or break.

SERVICING
THE BAIRD DISC MODEL "TELEVISOR"
By H. J. BARTON CHAPPLE, A.M.I.E.E.

THE ordinary Baird disc model "Televisor" (Fig. 1) is essentially quite a simple piece of apparatus capable of reproducing television images of good quality in the home. It serves the eye in a manner similar to that in which the loud speaker serves the ear, but, like the loud speaker, it cannot give of its best unless the signals passed to it are above suspicion.

Fig. 1.—THE BAIRD DISC MODEL "TELEVISOR."

Symptoms of Faults

Under normal use, therefore, it is necessary to be able to recognise certain symptoms when the apparatus does not appear to be functioning satisfactorily, as in this way the task of servicing is made much simpler. The numbered list gives the most likely untoward effects which may be observed, and methods of curing them will be dealt with in the same order. In this it will be recognised that many of the faults arise from the wireless set which is receiving the television signals, but in view of the paucity of information associated with the newest offshoot of broadcasting it was felt necessary to include these in the list to make the story quite complete.

1. Vertical black lines on image area.
2. Lateral image movement.
3. Bad image hunting (vertical).
4. Refusal of synchronising mechanism to hold image.
5. Noisy motor.
6. Failure of motor to start.
7. Image area diamond shaped irrespective of speed control knob position.
8. Neon lighting wrong way.
9. Image movements reversed.
10. Neon light intensity effected by switching on of motor.
11. Stationary light splashes on image.
12. Insufficient neon brilliancy.
13. Dark patches on neon plate area.
14. Vertical lines travelling across image.
15. Negative image.
16. Fine mesh pattern over neon area.
17. Indistinct image with light thrown up behind image and beardlike shadows.
18. Blurring or out-of-focus effect.

Essential Parts of a Baird Disc Model "Televisor"

Before dealing with these in turn it is advisable to consider briefly the four essential parts of a Baird Disc Model "Televisor."

The Aluminium Disc

The first of these is a disc of light aluminium perforated by a spiral series of apertures. The last three of these apertures and the first three are rectangles; the others are squares, the effect of this being to give an image with the fine grain concentrated at the centre, where the more important details of the picture are met with, and a rather coarser grain at the edges. This makes the most efficient use of the detail permitted by a 9-kilocycle band, which is all that can be transmitted through the B.B.C. medium-wave stations at present.

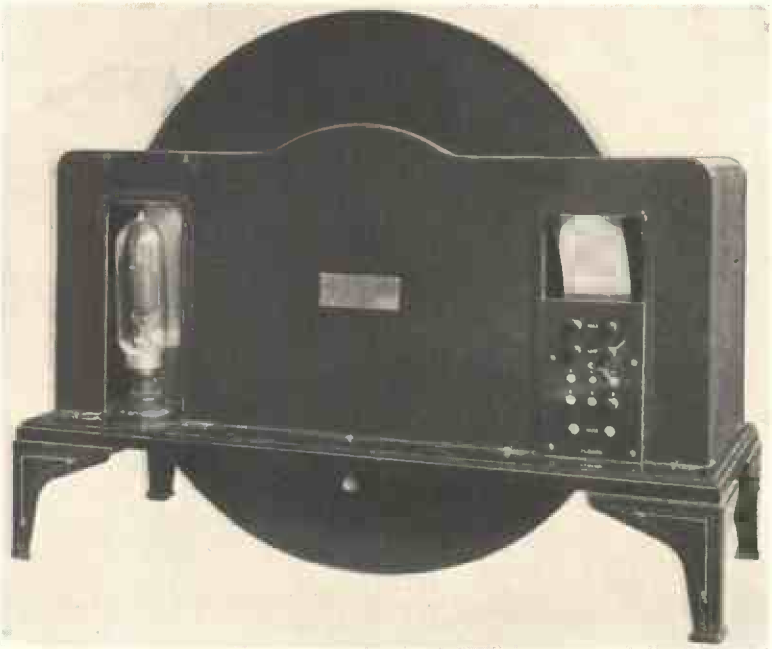


Fig. 2.—THE BACK OF THE "TELEVISOR."

To remove the main casing it is necessary to take out the wood screws passing into the wooden base through the casing lip edge at the back.

If the image area is diamond-shaped with lines sweeping downwards or upwards, the motor is running either too slow or too fast. This can be remedied by altering the position of the wandering lead terminating in a spade tag on the back terminal board which can be seen above.

The Electric Motor

The second essential is the electric motor to rotate the disc, and for this purpose a Universal motor, which can be run from any electric supply, either D.C. or A.C., is employed. This motor rotates the disc at 12½ revolutions per second, a speed which has been decided upon, after very careful investigation, as giving the best compromise with the given waveband permissible. A higher speed reduces the flicker, but tends to sacrifice detail within the allotted sideband.

The Synchronising Gear

The third component is the synchronising gear. It is essential that the receiver should revolve exactly *in step* with the transmitter, and to devise an apparatus which would accomplish this in a commercial form constituted one of the most serious problems in the construction of a commercial apparatus. The Baird Automatic Synchroniser makes use of the thin black strip dividing consecutive pictures to provide a synchronising impulse at the top of each line of the picture. This synchronising impulse of a frequency of 375 is fed to coils actuating electromagnets pulling upon the teeth of a cogged wheel. These teeth are separated from one another by gaps four times the width of the teeth themselves, and it is essential for proper functioning that the air gap between pole face and the tooth face should be as small as possible, something of the order of ·006 inch.

The Neon Tube

We now come to the Neon tube, the fourth item. In the Baird "Televisor" a mica-backed plate is used as the negative-electrode. This glow discharge is viewed by the observer through the perforations in the rotating disc, and its luminosity is controlled by the incoming television signal. The fluctuations of this lamp as viewed through the disc create the image, which is built up by the moving spot of light—the light being bright at the high lights and dim at the shadows, and moving with such rapidity across the field of view as to create the illusion of a moving image similar to that which obtains at the cinema.

How to Operate the "Televisor"

The method of operation of the "Televisor" is as follows:—

First of all the wireless receiver is tuned in to the television signals, broadcast on a wavelength of 261 metres at present. As, however, the signals must be amplified sufficiently to light the neon tube, and as, furthermore, it is essential that distortion should be reduced to the absolute minimum, good results can only be expected from a first-class wireless set with a properly designed L.F. amplifier.

Fig. 3.—How to Remove the Front.

The front must be pulled forward gently to ease it away from the metal strip normally holding it down in place.

Starting the Television Receiver

In operation the signals should first be checked by means of a loud speaker, and when the characteristic rhythmic hum is heard at full strength the television receiver can be started. The motor is switched on and then slowly speeded up by means of the rheostat on the extreme left. On looking through the lens, whirling reddish patches will be seen, which, as the motor speeds up, will resolve themselves into a succession of images moving rapidly downwards. As the motor attains the correct speed the motion of the images slows, and gradually comes to rest, being held in position by the synchronising device.

Adjusting the Motor Speed Rheostat

The picture, however, when synchronised may be split vertically, that is to say, you may see a face divided in two. To rectify this the image should be allowed to drift by adjusting the motor speed rheostat. When the correct position is obtained the image will hold in place if the rheostat knob is readjusted. A further final adjustment may have to be made by means of the framing knob in the centre. This rotates the synchronising device, and thus moves the picture up and down to get the final correct framing. All synchronising operations should be done slowly.

FAULT FINDING

If all these points are properly understood and the resultant image or func-

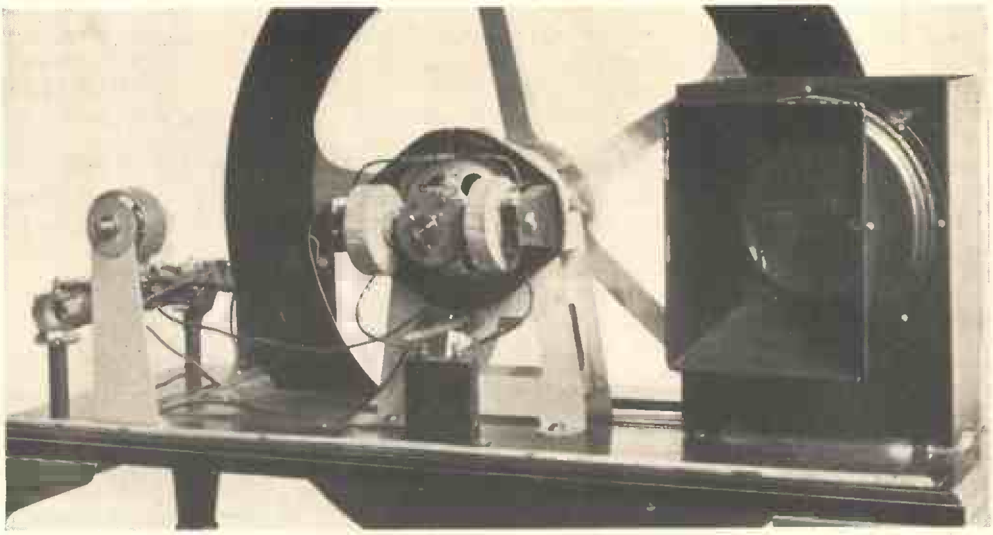


Fig. 4.—The "Televisor" with Case Removed.

tioning of the machine still seems to be at fault; then it must be overhauled.

Vertical Black Lines on Image Area

First of all the presence of stationary vertical black lines on the image may be due to interference from the 50-cycle A.C. mains. To cure this the position of the "Televisor" should be altered in case there is direct pick-up, and, in addition, run the mains leads to the motor in lead-covered cable and earth the lead covering.

Lateral Image Movement

Lateral image movement, that is, a "swaying" to left and right, can arise from a bent motor shaft or a disc out of centre.

Removing the Main Casing

To test this it will be necessary to remove the main casing. Remove both the front knobs by loosening the grub screws and slide off both the neon and terminal casings at the back. Then take out the wood screws passing into the wooden base through the casing lip edge at the back (see Fig. 2). Turn the "Televisor" on its side and loosen the screws passing through the baseboard from the underside into the front edge of the casing.

The front must now be pulled forward gently to ease it away from the metal strip normally holding it down in place. This process is seen in Fig. 3, and if any attempt is made to pull the casing too far forward it will foul the disc at the back and possibly damage it.

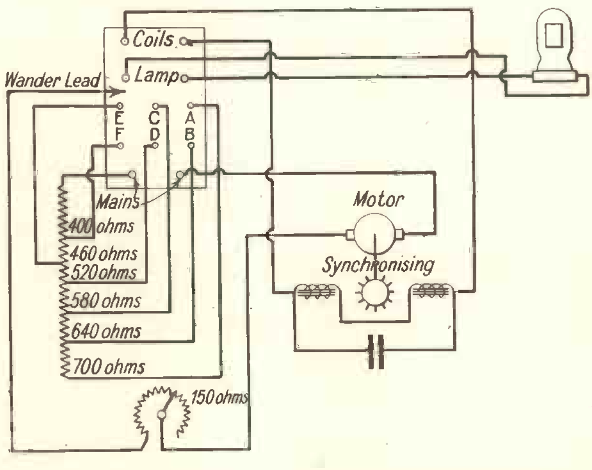


Fig. 5.—Theoretical Diagram of the Baird Disc Model "Televisor."

What to do if the Shaft or Disc is Out of Truth

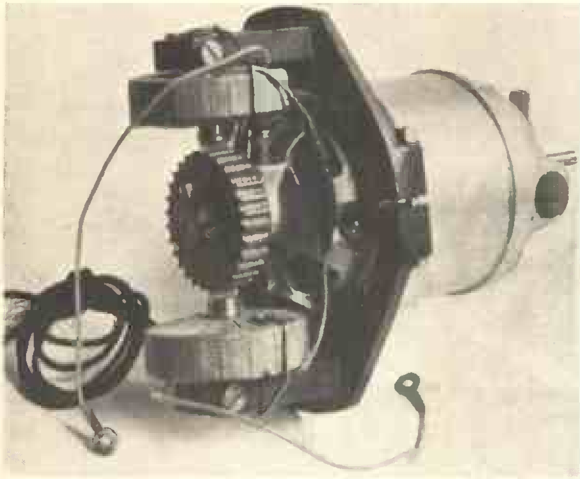


Fig. 6.—The Motor and Synchronising Mechanism.

Once the case has cleared the strip and two control spindles it can be lifted off, and the machine will then be as Fig. 4, the front metal strip on the baseboard, to which reference has just been made, being clearly visible. The motor can now be started in order to see whether the shaft or disc is out of truth. If the former, straighten it with light taps from a wooden mallet, but if the latter, it is advisable to replace the disc with a new one.

Bad Vertical Image Hunting

Bad vertical image hunting can arise from a variety of causes, but should be due primarily to an absence of adequate synchronising action. See whether every opposite pair of teeth in the cogwheel is in direct line with the pole pieces. Check the clearance distance between tooth edge and pole tip, this distance being ·006 inch or, as a fair guide, the average thickness of a safety razor blade. If not correct, close the gap by tapping gently the outside of the pole piece after loosening the screws gripping them in place.

Examining the Motor and Synchronising Mechanism

It may be advisable to remove the straps from the bracket holding the motor in place and lift out the motor and synchronising mechanism after having taken off the disc. This section of the apparatus will be seen in Fig. 6, and can now be subjected to closer scrutiny. Pass a direct current of not more than 25 milliamperes through the two coils as then joined in series and test with a compass to prove they are of opposite polarity (see Fig. 7). If not, reverse the windings on one coil. Remove any burrs that happen to be on the cogwheel teeth, using a very fine jeweller's file for the purpose.

Dismantling the Synchronising Mechanism

Try out the framing mechanism, and if this is sticky or has back lash, dismantle the mechanism completely, as in Fig. 8, and examine each part separately. The framework holding the coils must not bind on the cylindrical surface of the motor carcase. Remove any foreign matter and clean up the rubbing or sliding surfaces. When this has been done, reassemble, and the bad image hunting should then be cured. Of course it is assumed that the normal current of 25 milliamperes is being passed through the coils under working conditions and that the picture signal modulation superimposed on this from the receiving set's output valve is a strong one, at least $1\frac{1}{2}$ watts. The secret of successful television reception is bound up in the question of synchronising, and that is why so much attention must be paid to this part of the apparatus.

Refusal of Synchronising Mechanism to hold Image

If the synchronising mechanism refuses to show any tendency to hold the image steady—point No 4—then either one or both of the coils are disconnected (test here for continuity in the usual way) or, alternatively, the ·1 mfd. condenser joined in parallel across the coils may have developed a partial or complete short circuit. Remove the connections to the condenser and test this out in the normal manner and replace if defective.

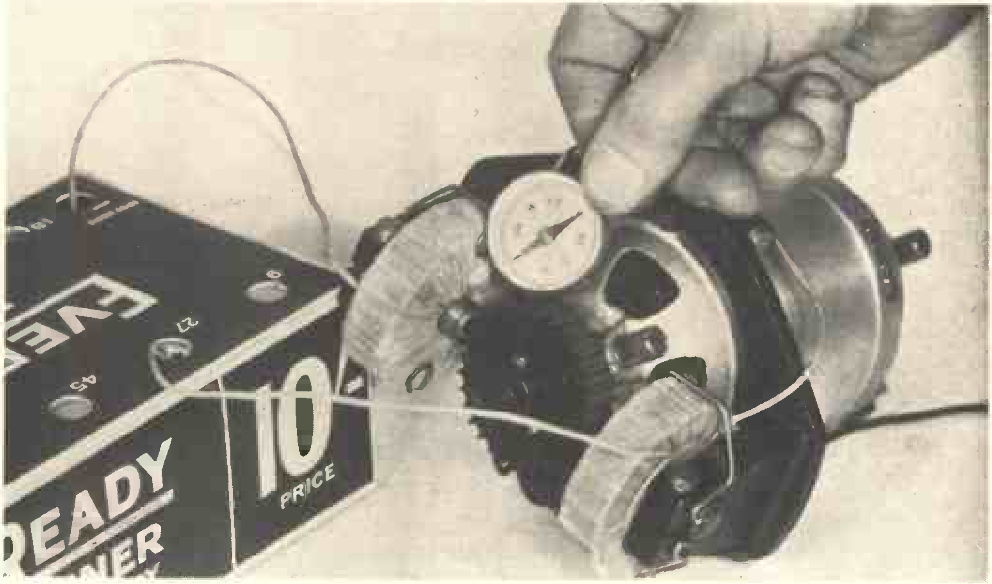


Fig. 7.—How to Test the Coils to see that they are of Opposite Polarity.

A direct current of not more than 25 milliamperes should be passed through the coils. If they are not of opposite polarity, reverse the windings on one coil.

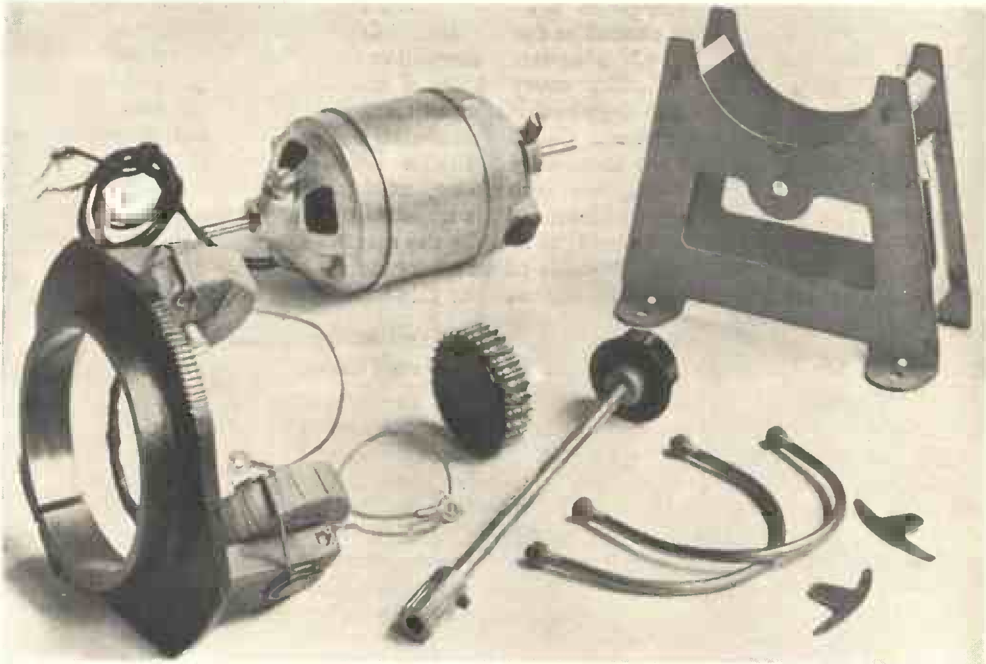


Fig. 8.—The Synchronising Mechanism Dismantled.

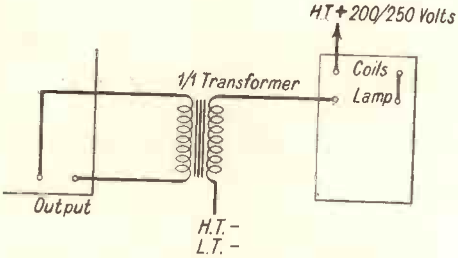


Fig. 9.—Wiring up the "Televisor" and Wireless Receiver.

With a receiver having direct or choke output the connections should be made in conjunction with an output transformer.

Noisy Motor

A noisy motor may be due to a tooth or teeth of the cogwheel striking a pole piece, and the remedy lies in resetting the position of the cogwheel, or the motor shaft may be slightly out of truth. Furthermore, a little lubricant may be called for, the cups for this purpose being at the top of the motor. The brushes may be chattering on the commutator, or one of the "micas" may be raised. Re-bed the brushes and thoroughly clean up the commutator with fine sandpaper.

Motor Fails to Start

Should the motor fail to start, trace through the main leads passing to the motor. The tapped fixed resistance and the variable resistance on the left-hand right-angled bracket are included in one of these leads, so continuity must be traced in both these. The moving contact on the resistance may be failing to make contact, or there is, perhaps, a break in one of the leads, which can be readily remedied.

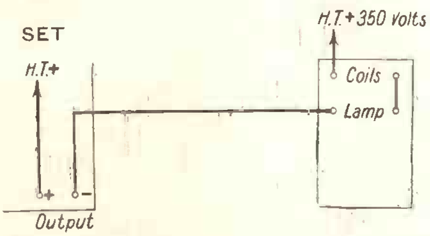


Fig. 11.—Wiring up the "Televisor" and Wireless Receiver.

This shows the connections used when a high voltage is available.

What to do if the Image Area is Diamond Shaped

If the image area is diamond shaped with lines sweeping downwards, then the motor is running too slow, while if diamond shaped with lines sweeping upwards, the motor is running too fast. This can be remedied by altering the position of the wandering lead terminating in a spade tag on the back terminal board, seen in Fig. 2. These terminals are marked A to F, and the tag should be inserted under each in turn so that the normal speed of 750 revolutions per minute is obtained with the moving contact of the variable speed control in approximately its central position.

Neon Lighting Wrong Way

The flat-plate neon lamp consists of a mica backed flat-metal plate with a

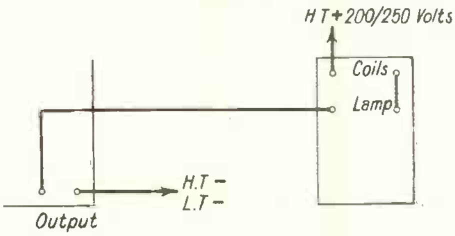


Fig. 10.—Wiring up the "Televisor" and Wireless Receiver.

This shows the connections when the wireless receiver includes its own output transformer

second electrode taking the form of a rod, seen in Fig. 2. The plate should glow evenly over the whole of its area with the characteristic reddish orange neon colour. If the bar is luminous and not the plate, remove the batten neon lamp holder and reverse the leads and the matter will be rectified.

Image Movements Reversed

When the image movements are reversed, that is to say, a head moved to the right at the transmitting end is shown as one moved to the left at the receiving end, it shows that the disc is mounted the wrong way round on the shaft. Loosen the grub screw in the disc boss, lift off disc and place back in same position on shaft but with the disc reversed to enable correct scanning direction to be made when disc is rotating.

Neon Lighting Intensity effected by Switching on of Motor

Sometimes it is noticed that the intensity of the neon lighting is affected by switching on of motor. This is caused by the leads to the motor being in electrical contact with the neon leads at the back of the terminal board. Take steps to separate them, adding a layer of insulating or binding tape, if felt desirable, to ensure they do not touch, and wholly or partially short through one to the other.

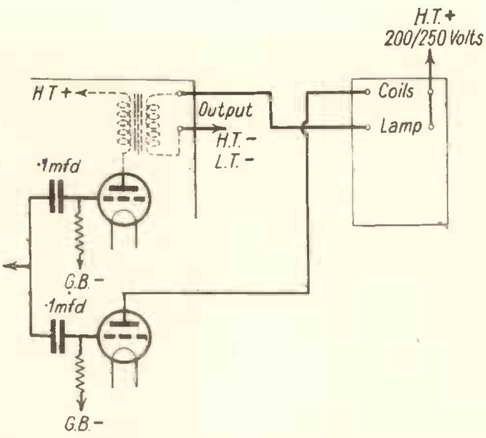


Fig. 12.—Using an Additional and Separate Synchronising Valve to Feed the Coils of the "Televisor" when the Set incorporates its own Output Transformer.

The same method is employed with receivers having direct or choke output, except that an output transformer is included in the connections to the lamp.

Stationary Light Splashes on the Image

Stationary light splashes on the image something like that shown by the white spots on Fig. 14 (by the way, the white spots may be black) are caused by the sparking on the commutator of the disc motor. Clean up the commutator with fine glass-paper, see that the brushes are properly bedded down and not broken, and under proper tension. If worn too far down, replace the brushes with new ones and bed down.

Clearing Motor Interference

In addition, another excellent way to clear motor interference is to place two 4-mfd. fixed condensers in series across the motor brushes. Then join the junction point of the two condensers either to the motor carcase or earth, or both. Each of the three possibilities should be tried in turn to learn which is the most effective. A convenient place on the motor, if the main casing is not taken off, is the bolt which passes right through the base-board for holding down the motor support.

Fine Mesh Pattern over Neon Area

Since Fig. 14 illustrates another possible defect, namely, Item No. 16 on our list, which is a fine mesh pattern over the neon area, we will deal with that now. This is due, generally, to heterodyning from an interfering station, and can only be cut out by using a heterodyne filter on the wireless receiving set. High-frequency machines as used by hairdressers, have a somewhat similar effect, and must be cured by prevailing on the user of those machines to install anti-interference devices. Sometimes the neighbour oscillating will cause a pattern of various shapes to flick across the screen, and the cure is obvious in this case.

Other Image Disturbances caused by Atmospherics

Dealing with other image disturbances, atmospherics show themselves as violent black or white flashes, which *momentarily* blot out part or all of the image. Then, again, if it is found that spots appear at different places on the picture, the trouble is most likely to be something other than the disc motor. Faulty light switches often cause mysterious black or white splashes.

Fine Rippling Interference

Sometimes a peculiar fine rippling interference, rather similar to the grain one can see if close to a cinema screen, is present. This effect is probably more noticeable as the distance from the transmitting station is increased. It is due to the minor atmospheric disturbances, and

Fig. 13.—THE CORRECT FEATURES AS SEEN ON THE BAIRD DISC MODEL "TELEVISOR."

Fig. 14.—HOW TO IDENTIFY FAULTS.
Stationary light splashes on the image are caused by the sparking on the commutator of the disc motor. (The white spots may be black.)

in sound reception can often be heard when the carrier wave is tuned in.

Insufficient Neon Brilliancy

Coming now to Item 12, insufficient neon brilliancy will arise from an inadequate current or voltage being fed to the neon lamp. Check over with meters to see that it has 200 volts across it and that the current passing through it is 25 milliamperes. If not, use an eliminator or super-capacity battery feed that will ensure this, otherwise the resultant image cannot be watched in comfort.

Dark Patches on Neon Plate Area

Dark patches on the neon plate area are a sure sign that the lamp is worn out and needs replacing, or has been over-run and thus damaged, so that a new one is called for.

Vertical Lines travelling across Image

When vertical lines are noticed to be travelling across the image this will, no doubt, be due to motor boating in the wireless set. Employ any of the standard methods for curing this (principally decoupling), but do not forget that if both the neon lamp and wireless set are being fed from the same H.T. source, it may be that the relatively large neon lamp load has caused a big drop in the available voltage. In consequence the valves are not being fed in the proper manner and a low-frequency oscillation will result. The only sure cure is an eliminator or large batteries capable of delivering a bigger output.

Negative Image—

We now come to a negative image, that is, one in which all the light parts are dark, and *vice versâ*, just like a photographic plate from which a contact print is made.

Whereas in aural reception no account has to be taken of phase, in television this is most important. A reversal of current direction will change a positive television image into a negative one, and since under working conditions these reversals take place in the wireless set as part of its normal functioning, at the output stage the current direction must be correct.

—And How it can be Cured

To rectify matters one can interchange the output terminals on the set, reverse *either* the primary or secondary windings on the transformer preceding the last valve, while if the set is R.C. coupled throughout on the L.F. side, then change the method of rectification, that is anode bend to leaky grid, or *vice versâ*, or add another stage of L.F.

Fig. 15.—How to Identify Faults.

This somewhat exaggerated effect of a white background behind a person's head, while the white background on either side had become almost black on the top, is one of the first things one notices in images lacking low-frequency. Other causes are overloading and too little high tension, or the neon or output valve incorrectly biassed.

Indistinct Image

We now come to the last two effects, which bring about imperfect images. These are shown in a somewhat exaggerated effect in Figs. 15 and 16. The first thing one notices in images lacking L.F. is a light thrown up behind a person's head, while the white background on either side has become almost black on the top of the picture on either side. As the artiste moves from side to side the white flare above the head will follow, but in most cases will be much less intense if the artiste turns side face. In some cases of L.F. loss a dark flare like a shadow will be present on the forehead, as in Fig. 15, just above the nose, also two beardlike shadows on the lower jaw either side of the mouth will be observed.

Effect of Overloading or too little H.T.

Other causes of these very objectionable shadows or throw-ups are overloading and too little H.T., or the neon or the output valve incorrectly biassed. As a general guide, any continual streaky shadows appearing to travel up the picture are a definite indication that the lower frequencies are not compatible with what is being broadcast, and the receiving apparatus is capable of improvement in an orthodox manner familiar to all readers.

General Blurring or Out-of-focus Effect

Lack of the higher frequencies is not nearly so objectionable as that of the lower. It has the pictorial effect of a general blurring or out-of-focus effect. Note the eyes, for example, in Fig. 15. One can well consider them as losing all the H.F. permissible. The sure cure is to broaden the tuning, that is, see that the high-frequency circuits are not ultra-selective.

Excess of High-Frequency

Another fault, though one which occurs somewhat rarely in broadcast reception of television, is an excess of high-frequency, which results in haloes above certain lines running horizontally, or nearly so, across the picture (see Fig. 16). Note the white halo followed by a secondary of the original image across the top of the head, the eyebrows, mouth and shoulders. These effects are due to methods employed to prevent the attenuation of the higher frequencies. All frequency boosters are some form of tuned circuit, and if too drastic in action will definitely oscillate, resulting in a negative image, the white halo, followed by a weaker positive one, being spaced according to the various factors of the circuit.

Resonance in Inter-valve Transformers

This form of trouble is sometimes found when an ordinary sound-receiving apparatus has been connected to a "Televisor," and, while not apparent to the ear, the eye quickly detects the fault.

Fig. 16.—How to Identify Faults.

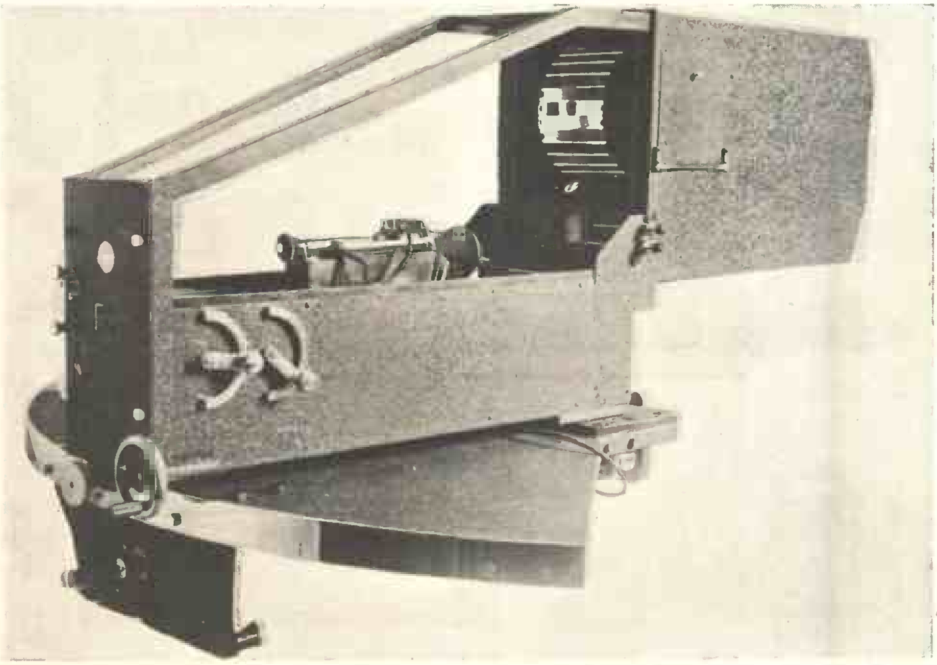
An excess of high-frequency sometimes results in haloes above certain lines running horizontally, or nearly so, across the picture.

The Cause of Resonance

The cause is due generally to a resonance in the inter-valve transformers, and may be cured by suitable damping.

Feed Back in H.F. Sections of a Receiver

The halo effect may also occur from feed back in the high-frequency sections of a receiver. Most receivers, unless of the band-pass type, will give a better picture when slightly out of resonance with the transmitting station.



The Newest Type of Televisor Transmitter made by the Baird Co. for the B.B.C. and used for the regular Television Transmission.

MAKING A START IN WIRELESS TRANSMISSION

By FRANK PRESTON

AT some time or other every keen wireless experimenter has a strong desire to extend his scope and sphere of activities by setting up a transmitting station. This is quite natural, because anyone who likes to know the "whys" and "wherefores" of things cannot possibly be satisfied by listening to programmes without having a practical understanding of how they are sent out.

For a few years past I believe that the new recruits to the ranks of amateur transmitters have been comparatively few in number, but recently there have been distinct signs of a revival in the transmitting movement. How should one set about the erection of necessary apparatus?

A Special Licence is Essential

Many people entirely overlook the first necessity of obtaining a transmitting licence, and I must strongly emphasise the fact that such a licence is absolutely essential before making any transmission whatever. Even if transmissions are to be made only on an "artificial" aerial, so that signals cannot normally be detected beyond the precincts of one's own home, an appropriate licence must first be obtained.

Conditions of Licence

A "Summary of Conditions of Issue" in respect to a transmitting licence can be obtained on application to The Secretary, General Post Office, London, E.C.1, so there is no need to state all those conditions here. Instead, reference will only be made to the more important ones, and an explanation of their meaning given.

The principal condition reads as follows: "Applicants must satisfy the Postmaster-General that they are qualified to conduct experiments of scientific value or public utility. If scientific research is intended they should be certified as competent investigators by a Government Department or some recognised scientific body. Authority to use wireless sending apparatus, even with an 'artificial' aerial (*i.e.*, a practically non-radiating aerial) can be granted only if the nature of the proposed experiments and other circumstances warrant that course."

From this it will be seen that it is useless to apply for a licence merely because you wish to chat with your friend in the next village, or to see how far your signals will carry when using a 60-volt high-tension battery and a 2-volt power valve.

It would be equally futile to attempt to obtain a licence on the strength of your desire to compare different circuits, or to experiment with alternative aerial arrangements. At the same time, any of the above reasons *might* be sufficient if you had in mind some new ideas on any particular subject, or if you could satisfy the P.M.G. that you had devised a new type of component or accessory which might prove of scientific value if it could be experimented with and developed by using it in a transmitting circuit, and if there were no other satisfactory way of testing.

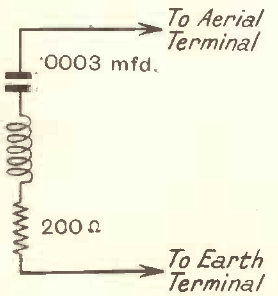


Fig. 1.—Arrangement of "Artificial" Aerial.

It is somewhat difficult to suggest lines of research because they will vary considerably in every case. And if such suggestions were made I am afraid that I might be guilty of "aiding and abetting" some people in obtaining a licence which they were not really qualified to hold.

Why these Conditions are Necessary

I can imagine a reader saying, "But why shouldn't anyone be allowed to transmit if he wants to?" The answer is, that the ether is already approaching a state of congestion, and a single irresponsible transmitter could be the cause of such interference that he might under certain circumstances spoil the reception of an important Government communication or an emergency SOS call, or, at the very least, the uninterrupted reception of broadcast programmes by a large number of listeners in his vicinity.

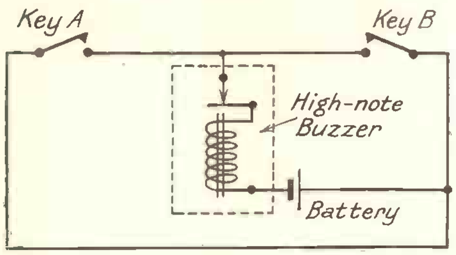


Fig. 2.—This shows the Method of connecting Two Tapping Keys to a Buzzer for Morse Practice.

Applying for a Licence

I must therefore leave the choice of the particular scientific work to be undertaken with the individual, and suggest what course should be followed after deciding on that matter. It is imperative that a clear and detailed statement of the proposed experiments should be given to the P.M.G.; there is no need to be afraid of divulging any particulars that might later be subject to patent rights, for they will be treated in strict confidence.

If you are a member of a scientific body or association, or have any qualifications in radio work, do not omit to mention the fact. Also obtain a signed statement from the Secretary or Bursar of the Institution or Examining Board to the effect that you are a fit person to hold a transmitting permit. Should you be employed by any Government Department and wish to carry out experiments which have a bearing on your occupation, there should be no difficulty in enlisting the aid of your Head, so long as he considers your proposed investigations as being of material value.

An "Artificial" Aerial

A very large proportion of the necessary experiments can be conducted on an "artificial" aerial and a licence covering the use of such a device is not so difficult to acquire. Incidentally, the only fee charged for a licence in respect to a transmitting licence for an "artificial" aerial is an annual one of 10s. As some readers may not understand the term "artificial" as applied to an aerial, an explanation will be useful. An "artificial" (sometimes called a "dummy") aerial is not an aerial in the usually accepted sense, but has all the electrical characteristics of one.

It should be arranged to have similar values of inductance, capacity and resistance to the elevated aerial which it is intended to replace. Fig. 1 shows how a fixed condenser, coil and fixed resistance are arranged to produce a satisfactory dummy aerial; suitable values for the condenser and resistance are indicated, while the coil may consist of about twelve turns of 20's gauge wire wound on a 4-inch diameter cardboard former. The fixed condenser should be of the mica type, suitable for a working voltage of no less than 800; it will never be subject to such a voltage but it will have to deal with high-frequency currents, and so an ample factor of safety should be allowed.

The Morse Code

When authority to use a radiating (or ordinary elevated wire) aerial is desired, stricter conditions have to be fulfilled. For instance, the operator must satisfy the Postmaster-General "by examination or otherwise" that he is capable of sending and receiving in the Morse code at a minimum speed of twelve words a minute. This qualification is necessary under international regulations, even when only telephony is to be used. The operator must also be capable of acting on any instructions given in the Morse code by Government or commercial stations.

The clause relative to the knowledge of Morse is probably more responsible than any other for the limitation of the number of persons holding a " full " transmitting licence. There is really no reason why it should be, because the Morse code is not difficult to master provided one is prepared to spend a reasonable time practising it. There are various ways of learning the code, but in every case it is extremely desirable that the student should work in conjunction with someone else. For this reason it is preferable to join a wireless society which runs regular Morse practice classes, but where this is impossible a friend can usually be found who will co-operate.

How to Learn the Morse Code

Before beginning practice in sending and receiving, the code should be thoroughly committed to memory. The Morse code symbols for the alphabet and for figures, etc., are given in Fig. 3 ; they are set out in alphabetical order, but many people find it easier to memorise them if they are split up into groups such as E, I, S, H ; T, M, O ; N, D, B, etc., so that the arrangement of signs follows a simple sequence. Others prefer to learn the symbols in pairs of opposites, such as E, T ; A, N, and so on.

Then, again, some find it easier when the letters are arranged in geometric patterns, but whatever system is followed the principle is the same, that the letters should be recognised by their sounds and not by their appearance on paper.

For this reason they should not be learnt as, say, dot–dash, for letter A, but as a more phonetic or musical sound, such as de–dah. It will be found considerably easier to learn the alphabet if the letters are read in this way rather than as their visible equivalent.

Morse Practice

When all the letters are known off by heart, practice is necessary in transmitting and receiving them in any sequence. This is best obtained, as explained above, by enlisting the aid of a friend, preferably one who is already conversant with the Morse code. You will require two tapping keys, a high-note buzzer and a dry battery or accumulator ; these should be connected up as shown in Fig. 2, so that either you or your colleague can transmit in turn by means of keys A and B respectively.

It might be of assistance to know that the tapping keys and buzzer can be obtained very cheaply from a number of firms who specialise in war disposals goods.

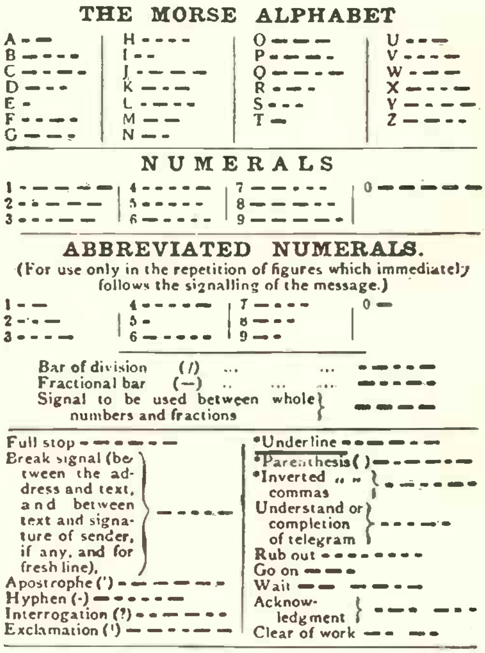


Fig. 3.—THE MORSE CODE.

Timing

Right from the beginning, be careful to adopt correct " timing " rules, which are as follows :—

(1) A dash is equivalent to three dots.

(2) The space between signals forming the same letter is equivalent to one dot.

(3) The space between two letters in the same word is equivalent to three dots.

(4) The space between two words is equivalent to five dots.

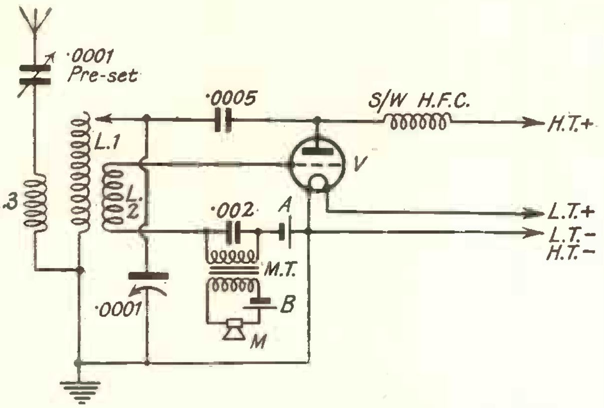


Fig. 4.—A very Simple Transmitter using a Single Valve as Oscillator and Modulator.

Values of Components :—

For 150—170 metres, L.1, L.2 and L.3 should have approximately 15, 12 and 8 turns of 20's gauge bare wire wound on 4-inch diameter formers ; L.1 should be fixed with L.2 and L.3 movable in respect to it. Tappings may be taken from L.1 if desired, to give a wider wavelength range.

V. is a power valve, such as Mullard P.M.256 for 200 volts H.T. and 6 volts L.T.

A. is 36 volt grid bias battery.

B. is 4 volt accumulator or dry battery for microphone.

M.T. is microphone transformer.

M. is microphone.

(The two latter can be bought together).

Power about 4 watts.

Licence Fees

Once the Morse code is known sufficiently well the licence can be applied for. If it is required to employ a maximum power of 10 watts (which is ample for practically all requirements), an initial licencing fee of 10s. and an annual fee of 20s. will have to be paid before the licence is granted. (Proportionately higher fees are charged for more powerful stations.) This charge is additional to the usual 10s. for the Wireless Receiving Licence, unless the receiver is to be used solely for experimental purposes—that is, not for receiving broadcasting programmes for entertainment. If called upon to pass an examination in Morse, a fee of 5s. will be charged in addition to those referred to above.

Designing the Transmitter

Having procured the licence it remains to erect the transmitter itself. In working out a design for the instrument it must be borne in mind that it will have to operate on short waves, and the following are the three bands of wavelengths which may be employed : 173·4 to 151·1 metres, 42·7 to 41·24 metres, and 21·38 to 20·88 metres. Under special circumstances transmission on bands of 10·7 to 10·02 metres and 5·35 to 5·005 metres will also be authorised. The instrument must therefore be designed on strictly low - loss principles and great care taken in the choice and arrangement of components. If voltages in excess of 200 or so are to be employed for high-tension supply it is also of obvious necessity that all components shall be of such construction that they will safely withstand the voltage load.

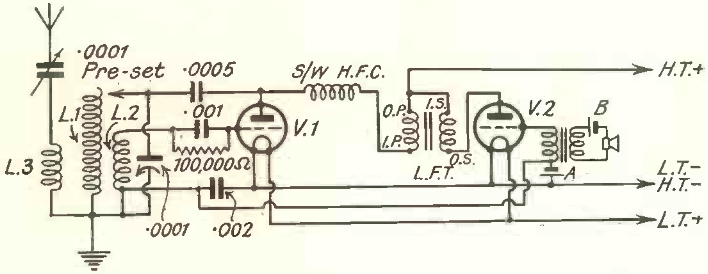


Fig. 5.—A 2-valve Transmitter in which V.2 acts as Modulator and Speech Amplifier, V.1 being an Oscillator.

Values of components as in Fig. 4 excepting : V.1 and V.2 are power valves, such as Mullard P.M.6, suitable for H.T. voltage of 150 and 6 volts L.T.

A. is 12 volt grid bias battery.

L.F.T. is large L.F. transformer, such as Varley D.P.3 (the transformer must be capable of carrying at least 10 m.a. in primary).

This circuit is rather better than that of Fig. 3, especially when only a low voltage of H.T. is available and where the maximum permissible H.T. current is under 20 m.a.

Power about 1·5 watts.

Simple Transmitting Circuits

The circuits of two simple transmitters are given in Figs. 4 and 5, where the values of the more important components are stated. In both cases ordinary battery valves are shown, and it is assumed that high- and low-tension supplies are to be obtained from batteries or an eliminator. If desired, indirectly heated A.C. power valves could be employed by modifying the low-tension circuits.

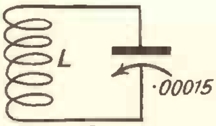


Fig. 6.—The Simple Arrangement of an "Absorption" Wavemeter.

The coil L should be the same size as L.1 shown in Figs. 4 and 5.

The transmitters represented by Figs. 4 and 5 are suitable only for use on a power of a few watts, such as might be supplied by large capacity H.T. batteries, H.T. accumulators, or a medium-sized eliminator, but they are ideally simple, and provide an excellent starting point for the beginner. Once their correct functioning has been secured, the operator will have gained possession of a wealth of knowledge which will guide him in designing and using more elaborate and modern arrangements, and it is much better to start with a simple set than to attempt the construction of an advanced model before having gained some insight into transmitting practice.

A Wavemeter is Necessary

Before connecting the transmitter to an outside aerial-earth system it is necessary that the operator should be in possession of some means of measuring and periodically checking the wavelength in use. A properly calibrated wavemeter is thus indicated. The simplest kind of wavemeter is one of the absorption type consisting of a tuning coil and variable condenser, as shown in Fig. 6 ; the coil should be the same size as L.1 specified for the transmitters shown in Figs. 4 and 5, whilst a suitable capacity for the tuning condenser is about ·00015 mfd.

Calibrating the Wavemeter

First, the meter should be calibrated by tuning in a few stations of known wavelength on the receiver. As each station is tuned in the wavemeter should be placed near to the aerial coil and tuned until the received signa suffers a maximum reduction in strength ; the meter is then tuned to the same wavelength as the signal When a number of readings have been obtained in this way a calibration graph can be drawn so that the wavemeter can later be quickly adjusted to any wavelength within its range.

Measuring the Wavelength of the Transmitter

To measure the wavelength of the transmitter a hot-wire ammeter of a pattern showing a full-scale deflection on about 250 milliamps should be connected in series with the aerial lead. (This can also be bought from a W.D. store, by the way.) Normally, the meter will give a steady reading corresponding to the amount of high-frequency energy being fed into the aerial, but if the wavemeter is brought near to the aerial coil a reduction in current will be observed as the meter is tuned to the wavelength of the transmission. At the point of maximum current reduction the meter and transmitter are tuned to the same wavelength, which can be read-off from the previously prepared graph.

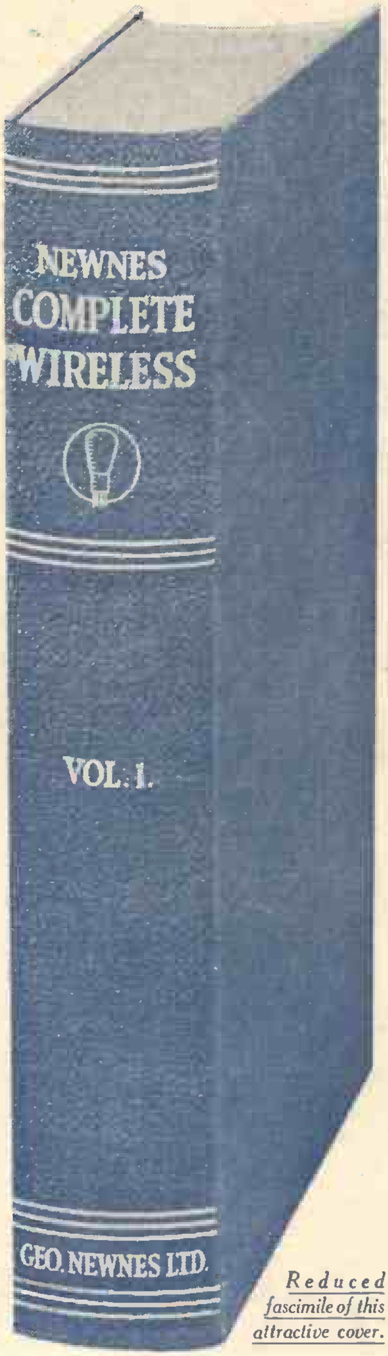
Wavelength to be Used

In general, correct functioning of the transmitter is most easily obtained on the highest allocated waveband (173·4 to 151·1 metres) and for this reason it is suggested that work should first be begun on a wavelength within this range. The approximate sizes of inductance coils given with Figs. 4 and 5 refer to the latter waveband, but correspondingly smaller coils can be made for shorter waves.

Join a Society

Practical assistance and co-operation are most desirable to the transmitting amateur, and all readers who propose to follow up this branch of radio science are strongly urged to join a local Society or to get in touch with The Secretary of The Radio Society of Great Britain, 53 Victoria Street, London, S.W.1, who will advise them of the address of the nearest affiliated Society.

Arrange the BINDING of your parts TO-DAY



Reduced facsimile of this attractive cover.

This Part completes Vol. 3

Don't hesitate, don't delay—bound immediately, before parts are lost or damaged, this comprehensive work will find a place on your bookshelf ready for immediate reference at any time. Do not waste the money you have spent in purchasing your parts of "Newnes Complete Wireless" by omitting to have the Work bound in the Publishers' authorised covers.

For utility, lasting service and good appearance these handsome binding cases in Imperial Blue Embossed Cloth with gilt lettering and design are ideal.

IMPORTANT

The Binding House of A. W. Bain & Co. Ltd., have arranged to receive and bind the parts of "Newnes Complete Wireless" in the Publishers' authorised Covers. Missing parts can be obtained at post free rates from the Publishers.

GENEROUS REDUCED PRICE OFFER

The cost of the case and binding each volume is 5/6. THIS PRICE HAS BEEN REDUCED TO 4/9 for all Subscribers who forward their parts of Vol. 3 for binding before Monday, April 10th, 1933.

URGENT

So that you shall not miss the opportunity of having your parts bound at this special reduced price, forward your parts of Volume Three for binding to-day.

ALL YOU HAVE TO DO

Send your parts (17 to 24) clearly marked with your name and address to A. W. Bain & Co. Ltd., 17-19 Bishop's Road, Cambridge Heath, E.2, together with P.O. or cheque for 4/9 (5/6 if after April 10th, 1933). Return carriage is paid on all orders in U.K. If parcels are not clearly marked, the binder cannot accept responsibility for delay or loss. Payments acknowledged and orders executed in strict rotation. Average time—three weeks.

A. W. BAIN & Co. Ltd.,

17-19 BISHOP'S RD., CAMBRIDGE HEATH · · · LONDON, E.2

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

COMPLETE WIRELESS

A PRACTICAL AND AUTHORITATIVE WORK FOR EVERYONE INTERESTED IN THE WIRELESS INDUSTRY

General Editor :

EDWARD MOLLOY

Advisory Editor :

RALPH STRANGER

VOL. IV

Contributors to Vol. IV :

SIR OLIVER LODGE, F.R.S.
J. P. McKENZIE, A.M.I.E.E.
FRANK PRESTON, F.R.A.
EDWARD W. HOBBS, A.I.N.A.
A. E. WATKINS
G. S. HOLIDAY
ALAN POLLOCK
H. H. DOWSETT
D. ASHBY, A.C.G.I., B.Sc., D.I.C.
C. F. ELWELL, Fell. Inst. Rad. Eng., M.I.E.E.
RALPH STRANGER
H. E. J. BUTLER
W. F. FLOYD, B.Sc. (Lond.)
W. W. WHIFFIN
J. H. A. WHITEHOUSE
T. SUTTON BRIGG
ERIC J. RIGBY, A.M.I.E.T., M.T.R.A.

GEORGE NEWNES LIMITED
SOUTHAMPTON STREET, LONDON, W.C.2

Index and Classified Key enabling all articles on any particular subject to be readily turned up will be found at the end of the Complete Work.

PRINTED IN GREAT BRITAIN BY THE WHITEFRIARS PRESS LTD., LONDON AND TONBRIDGE.

PREFACE TO VOL. IV

WE have been particularly fortunate in securing as a contributor to this volume Sir Oliver Lodge, F.R.S., whose article on "The Principle of Tuning" is of great interest. As will be seen, the patent which Sir Oliver took out in 1897 was the bottom patent for tuning to the end of its life, and it is interesting to note that it was considered to be of such importance that a seven years' extension of the patent was granted. It can safely be said that it is as a result of this patent that there is to-day a dial on every receiving set, whereby it can be put into tune with any transmitter, so that it readily responds to that one and to no other.

In view of the increasing interest taken in short-wave broadcasting, which has been greatly fostered by the British Broadcasting Corporation's Empire scheme, this subject has been dealt with thoroughly from the point of view of the man who wishes to construct a separate short-wave receiver, or convert his existing set for short-wave reception.

Amongst the recent developments in wireless which are dealt with in this volume, mention may be made of the articles dealing with "A Screened-grid Quiescent Push-pull Circuit," "Double Push-pull Receiver," "Push-push Amplification" and "The Quiescent Four"; while other developments dealt with include "Automatic Volume Control," "Tone Control," and "Automatic Grid Bias."

Another subject which we think will interest many readers is that dealing with "Sound Recording at Home." Whilst, of course, it must be borne in mind that wireless programmes are the property of the British Broadcasting Corporation and must not be reproduced, it will be readily apparent that there is wide scope for obtaining plenty of amusement with home recording apparatus.

We have continued in this volume the series of articles dealing with the servicing of standard receivers and the following makes are dealt with :—

Lotus
Kolster-Brandes
Gecophone
His Master's Voice
Consolidated Radio

In addition there are articles dealing with the servicing of well-known makes of electric gramophone motors and automatic record changers.

The important subjects of "Wireless Theory" and "Wireless Mathematics" have been carried to a conclusion in this volume, and there can be little doubt that reade s will find these two sections of the work not only useful but also highly interesting, thanks to the care which has been given by their respective authors to the difficult problem of presenting these subjects in a clear, sound and also attractive manner.

Tested circuits and useful charts and tables and a comprehensive glossary, the latter compiled by Mr. Ralph Stranger, make a fitting conclusion to what is, we believe, the most comprehensive practical treatise on broadcast wireless reception yet available.

E.M.

iv

CONTENTS

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

SPECIAL ARTICLE BY

SIR OLIVER LODGE

DESIGN FOR A CLOCKCASE RECEIVER

SERVICING LOTUS RECEIVERS

1/-

Part 25

IN 32 WEEKLY PARTS

PART 25.

THE PRINCIPLE OF TUNING

By SIR OLIVER LODGE, F.R.S.

Elliott & Fry, Ltd.

SIR OLIVER LODGE, F.R.S.

HARKING back to the year 1896, when the Marquis Marconi, accompanied by Sir William Preece, was stumping the country and interesting the public in a scheme for wireless telegraphy, which at that time was in an infantile state, I perceived that if it ever caught on and were developed into something important, a plan would be necessary for tuning up each station so as to make it more immediately receptive of the message intended for it, and so as to exclude all other stations which might be sending different messages. Marconi's patent had not been published, and was not published till late in 1897, but I knew the general lines on which he was proposing to work, for I had demonstrated the principle to the British Association at Oxford in 1894. There was nothing then but spark telegraphy, and the signals were sent and received in the dots and dashes of the Morse code. They were detected by some modification of the old coherer, and nothing like continuous waves, or what is called the "carrier wave" of high frequency had then been introduced. Each dot could be transmitted by a short series of electric oscillations, and each dash by a longer series of the same oscillations. In order to get tuning it was only necessary to find a way to make these oscillations definite and persistent, and to discover a method of tuning up the receiving station to them, so that it should respond to one particular frequency and reject others.

The rate of oscillation of a circuit depended on its inductance and capacity, in a way that had been known for a long time, ever since 1853 in fact, when Lord Kelvin gave the theory of electric oscillations in a paper called "Transient Currents." The term "self-induction" had not been invented at that early period. Lord Kelvin called it the "electro-dynamic capacity of the discharger," and contrasted it with the electrostatic capacity of a condenser. The discharge was influenced by both these quantities, now called "capacity" and "inductance." Clerk Maxwell had shown how to calculate the inductance of any coil, and a method of tuning consisted in adjusting the self-induction and the capacity, so that their product had a certain value, for upon that depended the frequency of the electric oscillation of the circuit.

Up to that time self-induction had not been much attended to, and there seemed some disadvantage in introducing it into the sender and receiver. But I perceived that the advantages would outweigh the defects by utilising the principle of syntony or resonance, whereby the sensitiveness of a receiver to a note to which it was attuned could be enormously increased, in spite of the lengthening of the wave and resulting diminution of radiating power which must inevitably be caused. There was only a certain amount of energy in each spark, and the plan which had at first been thought of was to utilise the whole of that energy for signalling purposes and get the coherer to respond to it. On the other hand, by putting self-induction into the circuit, the wave was lengthened, the radiating power was diminished; it was prolonged by the electromagnetic inertia, so that, instead of one or two oscillations, a dozen or more might be obtained, each of them weaker than if the whole power were concentrated in a single swing, but so that the combined effect of the lot operating on a tuned receiving circuit might be added together and give a cumulative effect.

But in order to effect this accumulation of feeble impulses and work them up to a maximum the circuit must be able to respond to them all, and to add them together. The simple putting into a battery circuit of a coherer as detector would prevent any accumulation, because its resistance was very high, practically infinite until it had cohered, which no one of the oscillations was strong enough to make it do; a series of weak oscillations could only be received by a perfectly conducting circuit, which, nevertheless, could not detect them. That difficulty had already occurred to me, and been overcome in the syntonic leyden-jar experiment, published in *Nature* a few years before (see *Nature* for February 20th, 1890, Vol. 41, p. 368). In this experiment the oscillations of one leyden-jar circuit were to excite similar oscillations in another completely closed circuit, which oscillations were to be detected by discharge at an included spark-gap; and yet if such spark-gap were permitted in the main circuit it would destroy any accumulation of impulses and prevent response. The receiving circuit had to be completely closed, or it could not respond to oscillations in the way intended. And yet, if it were completely closed, where would the spark-gap be put which was to display the result of the accumulated oscillations excited by the discharge from the sending station?

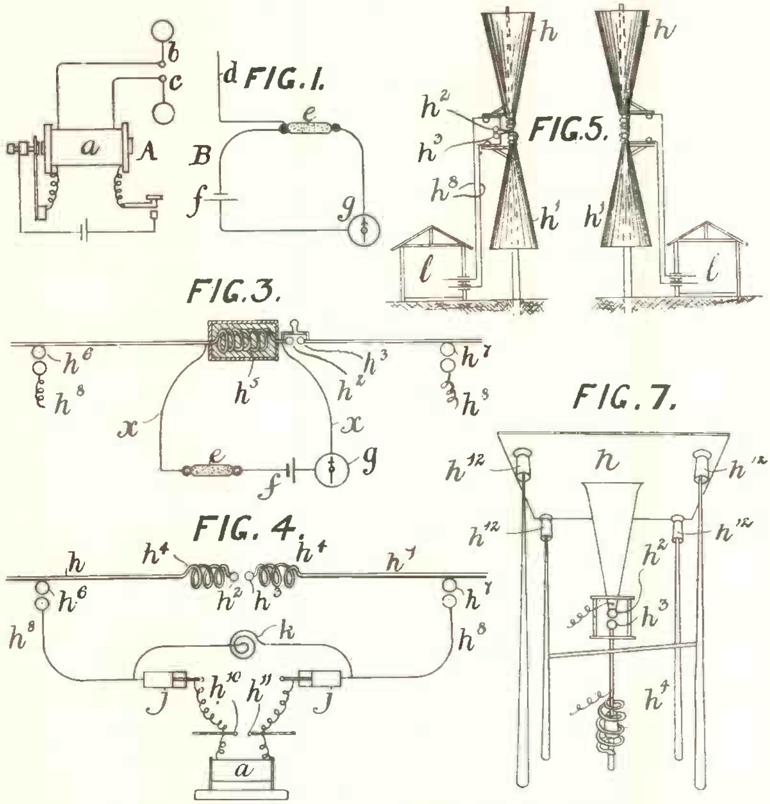
This difficulty and the mode of overcoming it has probably not been fully appreciated even now. The detector could not be put in the receiving circuit, or it would stop any response. The receiving circuit had to be a complete metallic closed circuit of perfect conductance. The spark-gap had to be arranged in a lateral circuit, or as a shunt, so as not to interfere with the main response; that is to say, the leyden-jar had to have two discharging circuits in parallel, one containing self-inductance, so that it could be properly attuned, with its circuit completely closed and made of low resistance; and then another circuit of infinitely high resistance, a short circuit containing only the coherer or a spark-gap adjusted so as similarly to unite the two coatings. The first circuit was for receiving the oscillations and working them up to a maximum; the second circuit, being of infinite resistance, was not in action until the oscillations had reached a certain amount, when the charge was able to overflow through the spark-gap and cause a spark. The spark occurred in spite of complete short circuiting of its terminals. Directly the spark occurred, the oscillations were interfered with, and the series of oscillations stopped; but they had displayed themselves in the spark, the signal had been given, and they were no longer wanted.

That is the arrangement: a condenser

joined up to self-induction in a complete metallic circuit of low resistance, which itself gave no sensible indication, but in which the surgings could increase if they were properly timed, and only if properly timed, so that the charges on the condenser plates should increase up to sparking potential, and then overflowed into a detector circuit also joining the plates, which remained inert and out of action until the charges arrived at a sufficient potential to enable them to jump the air-gap. It would do no harm to have a further condenser in that circuit, but there must be no self-induction, because no oscillations were required there; it merely had to come into action when the resonant circuit had worked itself up sufficiently to overflow.

The introduction of a subordinate condenser into that second circuit enabled a low-tension battery and galvanometer to be also introduced, for no current would flow until the spark occurred at the detector gap, which at first, in the resonant leyden-jar experiment, did not respond until some thousand volts were operating; and then the galvanometer or telegraphic instrument would also respond, for the spark offered a momentary conducting path to any current that wanted to go. Subsequently the spark-gap was replaced by a coherer, whose resistance was very great and able to stop the low-tension battery current, only allowing it to pass when the two metals had actually cohered, until they were separated again by a mechanical tap or some other means. This arrangement therefore could detect a signal by the deflection of a galvanometer or any other convenient method available when a current is initiated.

This was the form adopted as a tele-

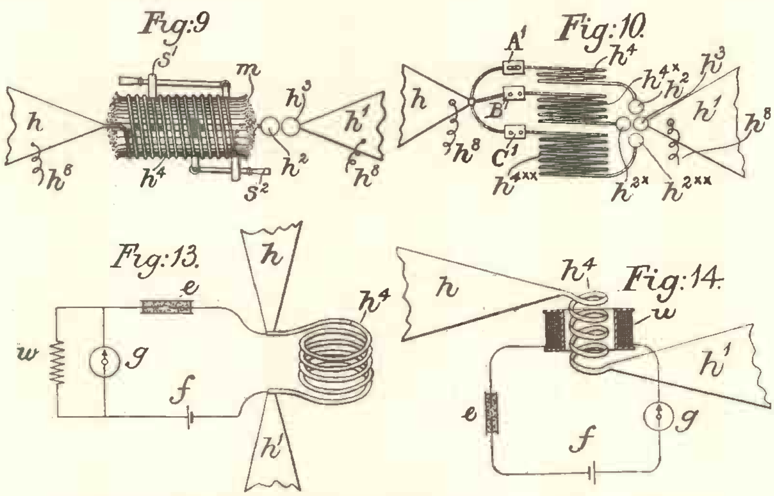


SOME OF THE DRAWINGS WHICH ACCOMPANIED PATENT NO. 11575 OF 1897.

graphic tuning arrangement. The receiving circuit was duplex, one part of it responding to the oscillations, however feeble, the other part detecting the result of this accumulation of impulses. That is the whole principle of tuning as at first designed, and fundamentally it remains the same now.

I patented the device in May, 1897, and it continued the bottom patent for tuning to the end of its life. In 1911 it would have expired, but it was felt to be important enough to make it worth while to try for extension of the patent. These extensions are not often given, and are only sanctioned if it can be shown that a patent was of great value, and that up to that time no adequate award had been received by the inventor. Parsons' steam turbine was one of those that was extended, and there were a couple of others. Anyhow, we made the attempt, sparing no expense in the matter of counsel. The action came before Lord Parker for a couple of days. Silvanus Thompson was one of the experts on my side; we were opposed by the Government, represented by Mr. Justice Sargant, and, on the second day, as the case seemed very important, by Sir John Simon, the then Solicitor-General. He had not been present at the opening of the case; he was coached up in the night by Mr. Justice Sargant, and showed himself very familiar with all the details when the time came for cross-examination. Lord Parker reserved his judgment. Afterwards he gave it in full, eliminating from the specification a few of the trivial claims and extending the important ones for another period of seven years. The case was decided entirely in our favour, and the Marconi Company at once made overtures to buy the patent. The case was not much noticed in the Press for some reason not known to me. The terms of the Marconi Company were accepted, and the patent was assigned to them, the Lodge-Muirhead syndicate which had been formed to run it being at once suspended and going into voluntary liquidation.

After this, in June, 1920, the Marconi Company had a case against the Admiralty and War Office and other Government departments for the infringement of this patent. The infringement had been going on all along, the Government being advised that the patent was invalid and that they were not infringing it. Accordingly, we had another trial, before Lord Moulton, which lasted twelve days, with counsel on both sides, and this time with Dr. Eccles as our expert to give evidence. Suffice it to say that we were entirely victorious in upholding both the validity and the infringement; the period of the infringement extending both to the time when it was in our hands, and, still more importantly, when it was in the hands of the Marconi Company.



A Further Selection of Circuits from the Famous Patent.
Showing alternative arrangements of the essential parts.

Every detail was gone into, including our publications, but the judgment was entirely in our favour; and since then there has been no question but that it was the bottom patent for tuning, and that it applied throughout and included all the changes which followed the introduction of the valve and the change from telegraphy to telephony. The result is a dial on every receiving set, whereby it can be put into tune with any transmitter, so that it readily responds to that one and to no other.

The illustrations on this and the preceding page are reproduced from British Patent Specification No. 11575 of 1897.

CLOCK CASE RECEIVER

By EDWARD W. HOBBS, A.I.N.A.

THIS unique receiver, pictured in Fig. 1, especially designed for COMPLETE WIRELESS, combines an all-mains receiver, dual balanced moving-coil loud speakers, and an electric clock worked direct from the mains, the whole enclosed within a special small grandfather clock-case, 5 feet 6 inches high, 17 inches wide and 12 inches deep, finished in Jacobean style. The one article, therefore, is an attractive piece of furniture, the most accurate of timekeepers, and a wireless set giving choice of over forty stations, with a tonal fidelity and quality of the highest character—thanks to the admirable "Cossor" kit set used in its construction and the correctly designed and balanced moving-coil loud speakers and the draped chamber in which they are housed.

Fig. 1.—THE CLOCK CASE RECEIVER.

Incorporated in this attractive piece of furniture are an electric clock, an all-mains wireless set and dual balanced loud speakers.

Entertainment Value

Too much stress cannot be laid on the vital importance of the entertainment value of any receiver, and in this respect the "Clock Case Receiver" is capable of ranking amongst the highest grade quality instruments, despite the fact that it does not cost more than about £17 10*s.* for a full set of parts, including clock and oak case.

Materials Required

The following comprises all the materials required for the construction of the complete instrument; no deviation should be made from the specified parts as the set has been most carefully designed so that all work harmoniously together.

RECEIVER.—1 "Cossor" Melody Maker "A. C." mains kit No. 338, complete but not including cabinet or loud speaker (*"Cossor" Ltd., Highbury Grove, London, N.5, or any reputable wireless dealer*).

ELECTRIC CLOCK.—1 Electric Clock movement with 6-inch silvered dial, hands and bezel complete, ready to fit into case (*E. Gray & Sons*, 18–22, *Clerkenwell Road*,

Fig. 2.—Back View of Clock Case Receiver.

Here can be seen at the top the electric clock in its separate compartment. Below it are the dual speakers in the draped sound chamber. The set is housed in the lower compartment, which has a door with a perforated zinc panel for ventilation.

*London, E.C.*2).

Clock-case.—1 "Complete Wireless" small Grandfather Clock Case by Hodgkinson Ltd., type No. 1800, obtainable through any clock makers or jeweller's shop.

Loud Speakers.—1 Balanced Pair of "Rola" moving-coil Loud Speakers, one with transformer, type F.5 P.M. ("*Rola*")

Sundries

Condenser. — ·005 mfd. Type 40 ("*T.C.C.*").

Flexible Wire.—6 yards "Lewcoflex" ("*Lewcos*").

Drapery.—1½ yards Black Velvet, 21 inches wide; ½ yard Gauze; 3 yards black Passé Partout Binding.

Terminals.—2, marked A.E. Type R. ("*Belling Lee*").

Plug.—1 Fused Plug, No. P22 ("*Bulgin*"); 1 Socket for same.

Speaker Fret.—1 piece Card 18 inches by 8 inches; 1 piece Yellow Silk, 18 inches by 8 inches.

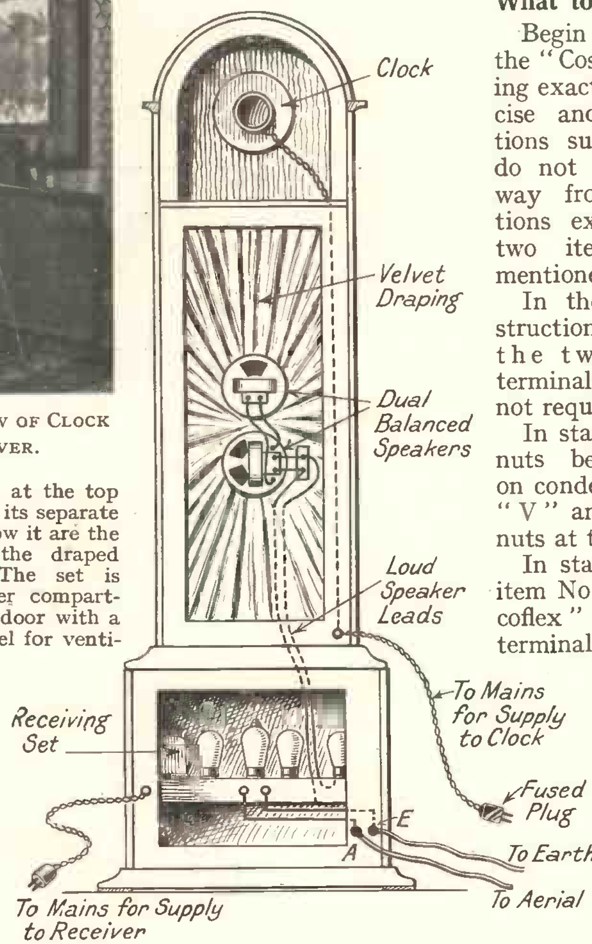


Fig. 3.—This Diagram shows clearly the important Connections to the Mains for the Clock and Receiver, also the Connections to the Loud Speakers.

What to do First

Begin by assembling the "Cossor" kit, following exactly the very concise and clear instructions supplied with it; do not deviate in any way from the instructions except for one or two items specifically mentioned in this article.

In the "Cossor" Instructions, Stage 1, omit the two loud speaker terminals F, as they are not required.

In stage 2, fit the thin nuts behind the dials on condensers "U" and "V" and fix the thick nuts at the front.

In stage 5, "Wiring" item No. 17, fit a "Lewcoflex" from anode terminal on valve holder D and leave it long enough to connect direct to loud speaker, about 36 inches is sufficient. Lead this wire up through the rubber bush near to valve holders C and D.

Stage 6, "wiring" item

No. 32. Connect a 36-inch length of "Lewcoflex" to terminal on Unit Y and lead it up through the rubber bushed hole connecting it later on to the loud speaker.

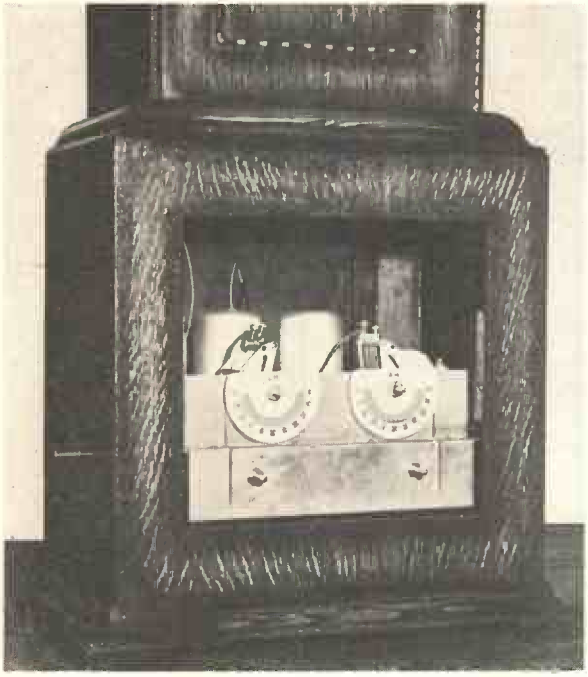


Fig. 4.—HERE WE SEE THE FRONT PANEL REMOVED TO SHOW THE COSSOR RECEIVER IN THE BASE OF THE CLOCK CASE.

Attention to Chassis

One other trivial alteration that has to be made to the chassis is to bend back the left-hand corner of the metal chassis—as shown in Fig. 5—the bend being started about ¾ inch from the corner. The metal has only to be bent backwards and this is done to enable the set to be inserted into the case without difficulty. The metal can easily be bent with a pair of pliers.

The Next Operation

The next step is to connect up the two "Rola" loud speakers—as shown in Fig. 6—the speech coils being connected in parallel and the input leads connected to the primary winding of the transformer.

These loud speakers are supplied in black dust-proof bags which must be removed while soldering the various wires to the tags, but should be replaced immediately afterwards.

Note the colours of the sleeving on the speech coil windings and connect them accordingly, black on one speaker to black on the second speaker, and so on.

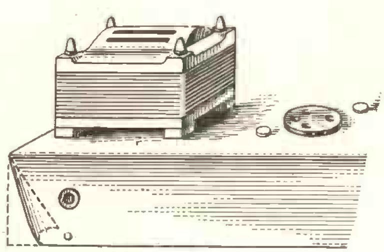


Fig. 5.—AN IMPORTANT POINT IN CONNECTION WITH THE CHASSIS.

The left hand corner of the chassis must be bent backwards as here shown.

Use "Lewcoflex" leads about 10 inches long for this purpose. Next, fix a small brass terminal in each of the two outer holes on the insulating plate on the transformer and connect them directly to the outer winding terminal tags on this insulating plate. The input leads from the set are connected to these terminals. The H.T. + lead goes to the terminal seen on the right in Fig. 6, but it is desirable to try the effect of reversing the leads, as results are perceptibly better when they are connected the right way round.

Sound Chamber

The next step is to prepare the sound chamber—which is the central compartment in the clock case.

Begin by marking out a piece of smooth card to the shape and dimensions given in Fig. 7, then cut it neatly to shape.

Next, cover one side with thin silk, fixing it with "Dex" or other prepared adhesive. Take care to have the silk quite flat; see that it is free from wrinkles or puckers; when dry trim off all surplus around the edges of the card and paste it

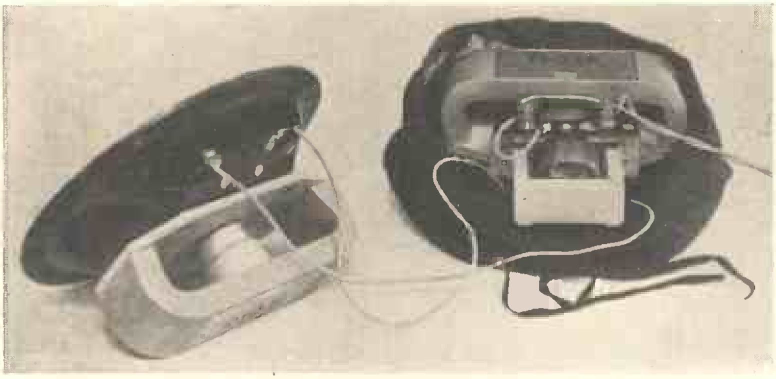


Fig. 6.—Connections to the Loud Speaker.

The speech coils on each loud speaker are connected in parallel. The input from the set is connected to terminals with leads to the outside tags connected to the primary winding of the transformer.

to the inside of the sound chamber, placing it centrally over the loud speaker frets. Hold it in place with drawing pins while the paste is drying.

Fixing the Loud Speakers

Now fix the loud speakers with ⅝-inch round-headed screws, placing the plain speaker uppermost with the permanent magnet horizontal with the terminals downwards.

Fix the second loud speaker with the magnet vertical and the transformer to the right.

Screw a ·005 mfd. T.C.C. condenser to the case, placing it parallel with the transformer, and connect the condenser to the loud speaker input terminals, as shown in Fig. 8.

Preliminary Test

The "Cossor" set should now be connected up to aerial and earth, the loud speaker leads connected to the loud speaker and the set then tested —before fitting it into the case.

Take care to adjust the A.C. voltage terminals on the set in accordance with the maker's instructions; the trial being satisfactory, disconnect the set and remove the valves. There is no need to spend much time over this preliminary trial; it is only done to be sure everything is so far in working order.

The Electric Clock

The Ferranti electric clock movement used in this set is only suitable for supply voltages of 200 to 250 volts alternating current (A.C.) 50 cycles, having time-controlled frequency; it will not work on D.C. mains.

Most of the electricity supplies are now time-controlled, but if in doubt, ask the electricity supply company. The principle on which these clocks work is that a small electro-motor fitted in the clock case revolves at a speed that is absolutely proportional to the supply frequency; it always runs at the same speed, and keeps exact time always.

Fixing the Electric Clock

The next step is to fit up the electric clock and the bezel. The movement, dial, hands and the cover glass with

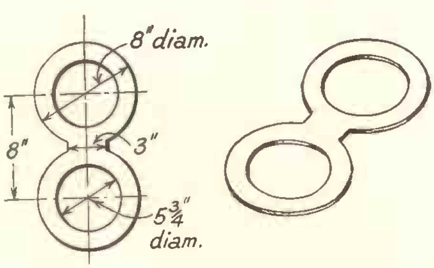


Fig. 7.—Foundation Card.

A piece of card should be cut to the shape here shown, covered on one side with silk and then glued over the speaker fret in the sound chamber.

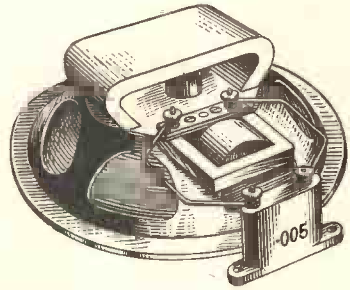


Fig. 8.—Condenser Connections.

A ·005 mfd. condenser is connected in parallel with the loud speaker input terminals.

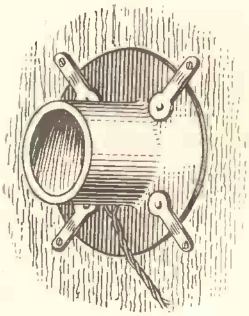


Fig. 9.—Fastening the Clock Movement.

The electric clock is held in the case by four clips and screws.

bezel or surrounding ring should be obtained from E. Gray & Son, 18 Clerkenwell Road, London E.C.2, who have made special arrangements to furnish this movement complete and ready to install in this special "Complete Wireless" receiver.

All that has to be done is to insert the movement from the front and fasten it by means of four clips riveted to the back of the flange plate. Turn these clips outwards so that they bear on the wood of the case — as shown in Fig. 9 — and fasten them with small screws.

Take care to see that these clips are tight and that the bezel and dial are held very securely, any trace of shake must be rigorously dealt with or the vibration when the set is playing will cause a most annoying rattle. If necessary, bed the flange plate and bezel on a narrow ring of paper or a few turns of cotton.

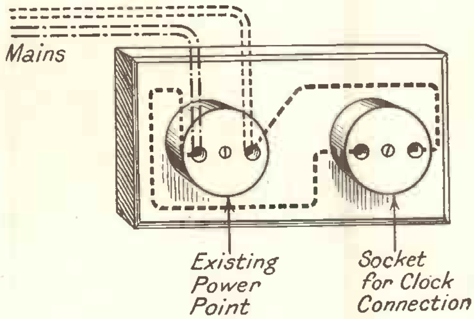


Fig. 10.—Clock Connections to Mains.

A plain 5-amp. shielded socket is connected, as shown dotted, across the A.C. mains or looped into an existing power point.

Clock Connections

A flexible twin wire is supplied with the clock movement, the ends of the two wires are connected to terminals in the clock case, the other ends have subsequently to be connected to a fused plug and socket.

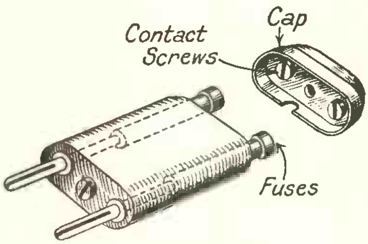


Fig. 11.—Fused Plug.

A plug that incorporates a pair of fuses should always be used to protect the clock from accidental short circuits.

First, however, pass the flex through a hole near the right-hand front corner of the top shelf, draw it up tightly enough to prevent it sagging or swaying, but do not have it unnecessarily taut.

Lead the flexible wire downwards and forwards through the sound chamber, keeping it clear of the woodwork, then bring it out through a hole at the right side

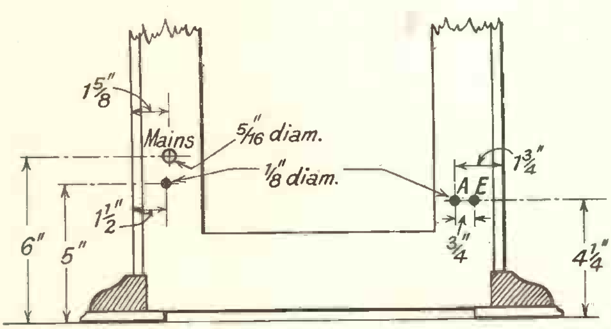


Fig. 12.—Holes in Back of Case.

Four holes must be drilled as here shown in the back lower part of the case.

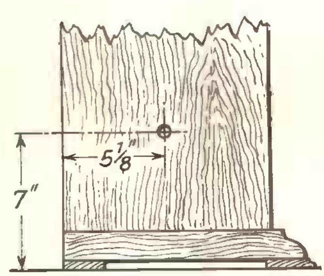


Fig. 13.—Position of Wave-Change Switch Hole.

A ⅜-inch diameter hole is drilled through the side of the case to allow the switch rod to pass.

of the case—as seen from the back—then note the position of the flex ; draw it out again, tie a knot in it and replace as before ; the knot is needed to avoid any pull coming on the wire and damaging the connections to the clock.

Connection to Mains

A standard 5 amp. socket must be permanently wired or looped in parallel to the back of an existing power socket—as shown in Fig. 10—using the existing pattrass or mounting block if it is large enough, otherwise a new one of suitable dimensions should be fitted and the sockets mounted thereon. Be sure to use good grade lighting cable for the connections and to make all connections secure, also see that all insulation is perfect.

A shielded socket, with recessed contacts, should be used to obviate any chance of accidental shocks.

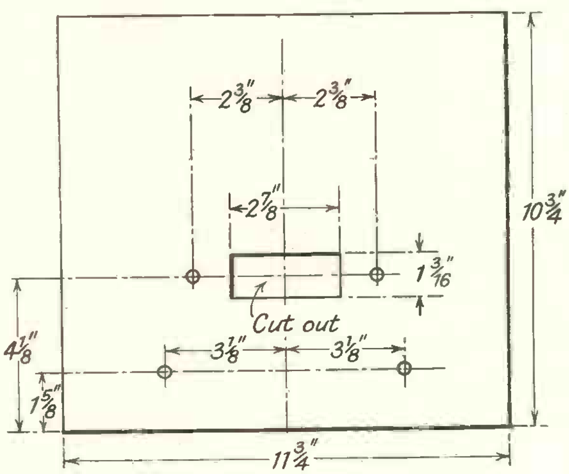


Fig. 14.—Detail of Front Panel.
The panel is drilled and cut out as here shown, and in accordance with the template supplied with the set.

Fused Plug

A plug incorporating a pair of fuses, as shown in Fig. 11, must always be used to protect the clock from accidental short circuits ; the ends of the twin wires are connected to screw contacts in the cap of the bakelite moulding, and access is obtained to it by unfastening the screw visible between the two prongs or plugs.

Having connected the flexible to the plug, insert it in the socket and twirl the small knob or starter at the back of the clock. This is revealed by removing the plated metal end cap, which is merely pushed into the outer casing and is easily pulled out.

Starting the Clock

The clock hands should then continue to revolve, but if they do not or they tend to turn backwards, reverse the plug in the socket and start the clock again—it will then run correctly.

Adjust the time by turning the larger of the two knobs at the back of the case. Set the time exactly to the B.B.C. time signal, then forget all about the clock ; it will continue to run and keep exact time so long as the electric supply does not fail.

Fixing the Set

The receiving set can now be fixed in place, it merely rests upon two bearers 9 inches wide, $\frac{3}{4}$ inch square, fixed to the sides of the lower compartment. The top of the bearers should be $4\frac{3}{8}$ inches above the floor of the case.

Four holes must be drilled through the back of the case, as shown in Fig. 12, and another in the left-hand side of the case, as seen from the front ; this hole is to allow the wavechange spindle to pass, and should be drilled as shown in Fig. 13.

As it is imperative that this hole is exactly in line with the switch rod, it is recommended that a small pilot hole be drilled first and its correctness tested by inserting the set into the case and putting a straight wire through the hole, any necessary adjustments can then be made without disfiguring the case.

The left-hand hole at the back of the case for the mains lead must be exactly in line with the rubber bushed hole in the chassis and may similarly be tested.

Aerial and Earth Terminals

Terminals are fitted to the lower right hand pair of holes in the back of the case, and are to have a suitable length of wire connected to each on the inside of the case so that they can subsequently be connected to the aerial and earth terminals on the chassis.

Having made all these preparations insert the set into the case, put it in diagonally with the mains transformer at the "high" end, while the other end of the chassis rests on the bottom of the case.

Placing the Set in Case

Stand at the left of the case so that the right hand holds the chassis at the back and the left hand can guide it from the front, the panel being taken out for this purpose. The chassis is a close fit in the case, but if inserted as before mentioned it can be raised up until the "low" end rests on the right-hand bearer, after which the transformer or "high" end is pressed down on to its bearer.

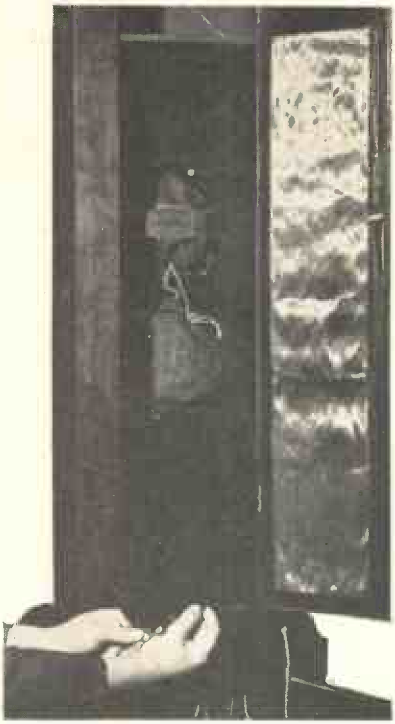


Fig. 15.—This shows how the Velvet is Draped in the Sound Chamber.

Mains Lead

The mains lead (stage 6, item No. 39 in the "Cossor" instructions) must be removed from the chassis before it is put into the case, the lead is then put through the hole in the case and re-connected to the receiver ; before the latter is inserted into the case, and while this is being done, the lead must be drawn outwards through the hole. Take care to see it is quite free when the chassis is in place.

Secure the chassis with a single round-headed wood screw at the right hand end, and with a small bolt and nut through the case and chassis beneath the mains lead hole, then connect the aerial and earth terminals.

Front Panel

The front panel is held in place by a few cabinet pins and can readily be removed or replaced.

Drill the holes and cut out the escutcheon hole in accordance with the "Cossor" template and the diagram Fig. 14; if necessary, chisel away a little of the wood at the back around the spindle holes to allow the fixing nuts to clear.

Draping the Sound Chamber

Drape the sound chamber with black velvet fixed with drawing pins. Start at the top, work downwards, fold the velvet around each speaker, fasten the edges just inside the doorway opening.

This draping is most important, it improves the tone.

Paste the gauze to the inside of the door and finish by gumming strips of black passé partout binding over it.

Test Results

The power and response of this set with the dual speakers is really remarkable—*on a first test* thirty-nine stations were brought in at full loud speaker strength, in one hour ; many American transmissions on the medium waveband can be tuned in at loud speaker strength on any favourable night. The following are dial settings of some of those regularly received :—

Name.	Call.	Right Dial.	Left Dial.
Boston . .	WHAS	22	12
Philadelphia .	WCAU	28	20
Rochester . .	WHAM	32	24
Atlantic City .	WPG	33	25
Cleveland . .	WTAM	34	26
Hartford . .	WTIC	36	28
Chicago . .	KWY	37	29
East Pittsburgh .	KDKA	43	38
New York . .	WABC	55	50
Minneapolis .	WCCO	61	59
Boundbrook .	WJZ	65	62

A SCREENED-GRID QUIESCENT PUSH-PULL CIRCUIT

By H. H. DOWSETT

IN the following article will be found details for constructing a receiver in which two pentode valves are used in quiescent push-pull. This receiver is actually a variation of the Screened-grid Pentode Two described on p. 22. The variation affects only the low-frequency amplifying stage of the receiver, and is for those who wish to operate a moving-coil loud speaker satisfactorily. *It has been found that the moving-iron type of speaker is not practicable with this form of output.*

H.T. Consumption is Hardly Increased

The increased amplification is obtained by adding another pentode valve, coupled to the existing one in quiescent push-pull, an arrangement which gives an undistorted output of well over 1 watt, comparing very favourably with many all-mains sets. The increase in high-tension consumption is very slight, and remains well within the capacity of even the smallest dry battery. The reason for the H.T. consumption being only slightly increased is the fact that, with pentodes in push-pull, the current varies in proportion to the signal received, thus when no signal is received the current consumption is negligible, whereas with a single-valve output the consumption is constant, regardless of the signal.

There is one rule which should be borne in mind when operating pentodes in this manner. It is inadvisable to remove a valve or break any other circuit unless the filament circuit of the valves has been previously broken. This applies to the

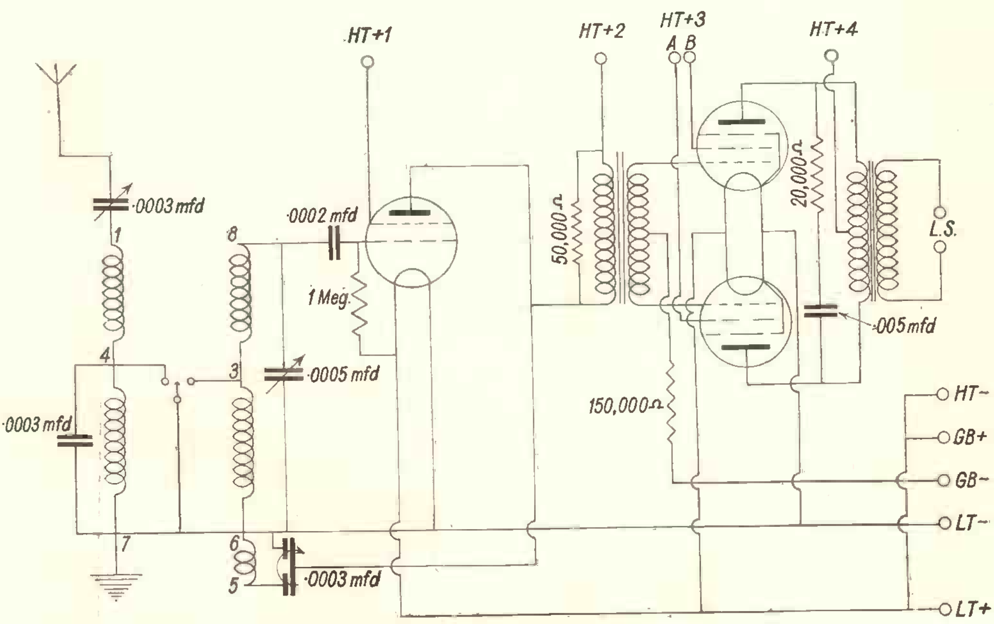


Fig. 1.—Theoretical Circuit Diagram.

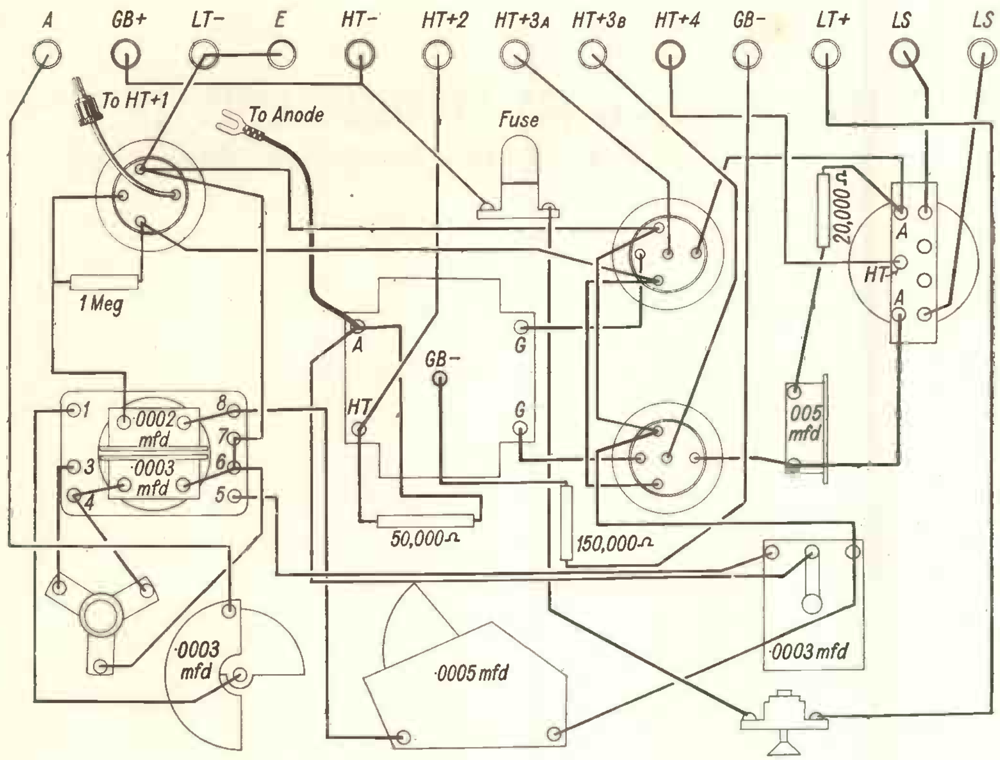


Fig. 2.—LAYOUT AND WIRING DIAGRAM OF THE RECEIVER, USING TWO PENTODE VALVES IN QUIESCENT PUSH-PULL.

adjustment of the grid bias and high-tension voltages, as well as to the actual wiring of the set.

To save repetition, reference is made to the original article where the information applies to both arrangements.

No further controls are added to the front panel, the arrangement of which is shown on p. 23. It would be as well, though by no means essential, to increase the panel and baseboard to about 14 inches.

Components Required

The complete list of components required for this arrangement is as follows :—

1 ·0005-mfd. variable condenser, with slow-motion dial (*Jackson*).
1 Dual range H.F. coil (*Telsen or Colvern RM2S*).
1 ·0003 mfd. Solid dielectric variable condenser with shorting position (*Ready Radio*).
1 ·0003 mfd. Differential reaction condenser.
1 Q type intervalve transformer. Ratio 8 : 1 (*Radio Instruments*).
1 Q type output choke (*Radio Instruments*).
1 3-point switch (*Polar*).
1 2-point switch.
2 5-pin valve holders.
1 4-pin valve holder.
1 Fuse and holder.
1 ·0003-mfd. fixed condenser (*Dubilier*).
1 ·0002-mfd. fixed condenser (*Dubilier*).
1 ·005-mfd. fixed condenser (*Dubilier*).
1 1-megohm grid leak.
1 150,000-ohm resistance (*Lewcos*).
1 50,000-ohm resistance (*Lewcos*).
1 20,000-ohm resistance (*Lewcos*).
13 Terminals.
1 Valve screen (*Six Sixty Radio Co.*).
1 Screen-grid valve, metallised (*Mazda*).
2 Pentode valves. Type Pen. 220 (*Mazda*).

Constructional Details

The constructional details given in connection with the original circuit apply also to the new arrangement, and should be read carefully before attempting to build the set.

The theoretical circuit is shown in Fig. 1, and the layout and wiring diagram in Fig. 2.

Arranging the Valve Holders

In arranging the valve holders for the two pentode valves one point should be carefully noted. One of the filament legs of the Mazda valve is marked with the figure 3 on the base. This figure marks the end of the filament, to which the outer grid is connected, and the valve holders should be wired in such a way that the sockets, to which these marked legs correspond, are each connected to the negative lead of the L.T. accumulator.

Grid Bias

The grid bias recommended by the makers should be applied to the pentodes, and the valves balanced by means of the screen voltages. If a milliammeter is available, it should be inserted into the anode lead of one of the pentodes and the screen voltage adjusted until a reading of 1·25 m.a. is obtained. The meter is then transferred to the other valve and a similar reading obtained.

Operation

In operation the set is identical with the original " Screen-grid Pentode Two," and details regarding this will be found on p. 25.

A later article by Mr. J. Poliakoff deals thoroughly with Quiescent Push-Pull, together with constructional details of Q.P.P. output stages using pentodes and triodes.

A CIRCUIT TESTER

FIRST construct an open box 6 × 2½ × 2¼ inches. Down each side ⅜ inch nail pieces of wood to support the top. In the middle of the top drill a hole large enough to accommodate a flash-lamp bulb, and solder two wires on to the bulb, connecting one to the bottom of a long flash-lamp battery, and after passing the other through a hole in one end, fix a crocodile clip.

In the middle of this end drill a hole so that the brass cap of the battery partially fills it. To keep the battery in position wedge a block 1 inch square between the other end and the bottom of the battery.

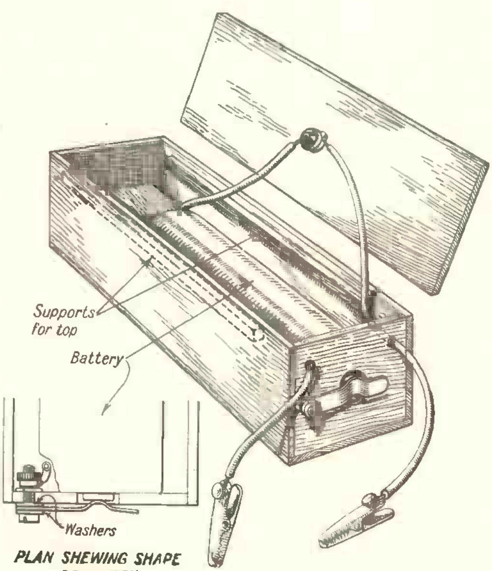


Fig. 1.—Details of the Circuit Tester.

Next construct the switch, which consists of a nut and bolt holding in position a piece of springy copper (shape shown in diagram). Inside the box on the bolt solder a piece of wire, which passes through a hole just above this hole the bolt occupied, and on to its end is fixed a crocodile clip.

When in use connect the two crocodile clips to the circuit to be tested, then press the copper switch, and provided the circuit is O.K. the lamp will light.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XIX—A GENERAL SURVEY OF RECEIVING CIRCUITS

THERE are many wireless experimenters who imagine that there is a very large number of different receiving circuits, while there is really a very limited number of basic connections.

This belief has been fostered by the so-called semi-technical journals, who, since 1923, published a "new" circuit practically every week. Mark you, I am not decrying this practice, as all the variations of well-known circuits offered to the public for construction, if they do nothing else, keep alive the experimenting spirit. There is no doubt that this experimenting in results that can be obtained with the various types of receivers led to an enormous improvement in the design of components and, therefore, the technical editors and the public have helped to a very great extent the development of the radio art.

But, nevertheless, the experimenter should not lose from view that it is the basic circuits that should be studied, if knowledge is to be obtained, and that many of the so-called "new" methods of valve coupling are merely modifications and refinements due to the ingenuity of the designers.

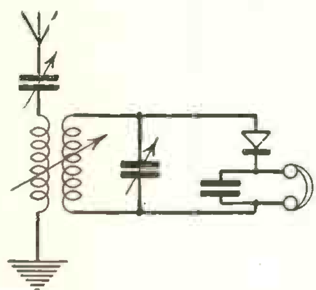


Fig. 1.—A TYPICAL CRYSTAL RECEIVER CIRCUIT EXPLOITED COMMERCIALLY DURING THE FIRST FEW YEARS OF BROADCASTING.

Theory Essential

There is one thing to be noted. Mere construction of new circuits without understanding the theory behind these circuits is a waste of time as far as experiment goes, apart from providing the family with a good receiver. Build your sets by all means, and experiment, but do not neglect your theoretical studies. The so-called practical man without knowledge of theory is just aping the blue-prints without knowing in the least what he is doing.

In the Early Days

Wireless reception started before the valve was invented.

At first detection of Morse signals has been carried out with the help of the coherer, which led to crystal detection. The crystal detector is an efficient piece of apparatus, and even at the present time, provided that selectivity is not the prime consideration, it is hard to beat for sheer quality of reception.

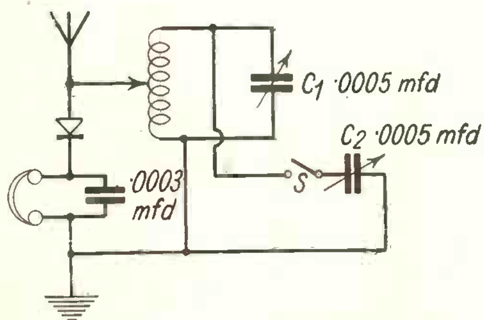


Fig. 2.—CRYSTAL CIRCUIT RECOMMENDED BY THE BRITISH BROADCASTING CORPORATION ENGINEERS.

This has a larger degree of selectivity than the usual type.

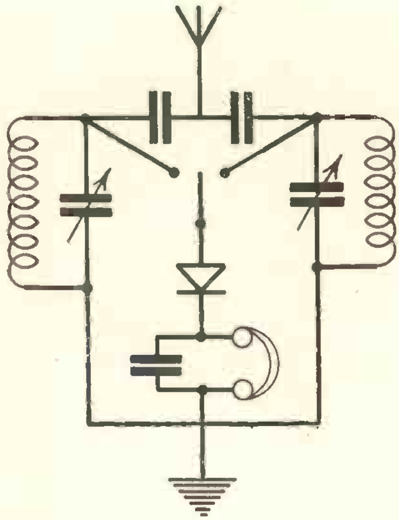


Fig. 3.—THE *World Radio* EXCEPTOR CIRCUIT.

An interesting circuit in connection with selecting two stations.

Developments Likely in Crystal Reception

There is far more in crystal reception than meets the eye, and I am confident that a time will come when experimenters will take up once more this humble radio component and will study its properties anew. The reason for such optimism on my part is that we have not the slightest idea why a crystal has unidirectional conductivity. There are many theories on the subject, but up to the present nothing has been proved definitely. When the time comes and the action of the crystal will become to us as clear as that of the valve, we may advance a step further in crystal reception.

In Fig. 1 is shown a typical crystal receiver which has been exploited commercially during the first few years of broadcasting.

The crystal used may be a combination of a crystal and a catswhisker, or that of two crystals. Those of my readers who are interested in the subject will find a wealth of material in connection with crystal reception and the various types of crystals in my book, "The Outline of Wireless" (Geo. Newnes Ltd.).

Selectivity with Crystal Receivers

Since the advent of the regional scheme of broadcasting, the old type of crystal receiver became somewhat out of date, on account of its limited selectivity, and new circuits have been advocated for the purpose of separation of the twin transmitters. In Fig. 2 is shown a crystal circuit, recommended by the B.B.C. engineers, which has a larger degree of selectivity than the usual type.

Please note the position of the telephones. With such an arrangement, when the switch S is open, one programme will come in and when the switch is closed the two condensers C_1 and C_2 being in parallel will tune in another programme.

World Radio Exceptor Circuit

Another interesting circuit in connection with selecting two stations is shown in Fig. 3, and is due to Mr. E. Redpath. This is the *World Radio* exceptor circuit. There, again, a selective switch is used. Note the two condensers in series, between which the aerial is connected. The values of the condensers and coils will depend upon the aerial used and the wavelengths which it is desired to receive.

Circuit using a Carborundum Detector

In Fig. 4 is shown a circuit described by G. C. S. in *World Radio*, in the issue dated September 5th, 1930. The designer is using a carborundum detector, which

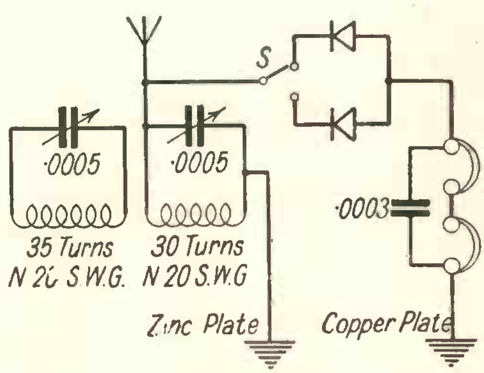


Fig. 4.—CIRCUIT USING A CARBORUNDUM DETECTOR.

An interesting circuit that is well worth experimenting with.

normally requires a polarising battery. This polarising battery is replaced by a twin earth, of which one consists of a zinc plate and the other of a copper plate, both buried in the ground, edge on, about 3 feet down and some distance apart. Each plate is 2 feet square. The earth leads are of 16 S.W.G. It is claimed that a considerable E.M.F. is obtained across the buried plates, in any case considerable enough to enable the experimenter to do away with the polarising battery.

Here you have something that is worth experimenting with.

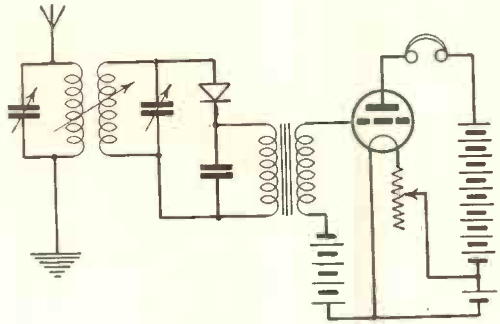


Fig. 5.—METHOD OF ADDING A VALVE AMPLIFIER TO A CRYSTAL RECEIVER.

Adding a Valve Amplifier to a Crystal Receiver

The method of adding a valve amplifier to a crystal receiver is shown in Fig. 5. It is also possible to have a stage of high-frequency amplification with a crystal detector, as shown in Fig. 6. In this case the crystal is placed in series with the primary of the intervalve transformer. The first valve is a H.F. valve, the detector valve is replaced by the crystal, and the last valve is the L.F. valve.

An Interesting Single Valve-Crystal Circuit

An interesting single valve-crystal circuit is shown in Fig. 7. This you will find fully described in "Wireless Valve Receivers and Circuits," by R. D. Bangay and N. Ashbridge. This is a sort of a feed back circuit, which was very popular a few years ago.

For experimental purposes you could do worse than to try a combination of a crystal and a pentode valve, as shown in Fig. 8. I do not know of anybody having bothered to check up on this, but the results are highly intriguing.

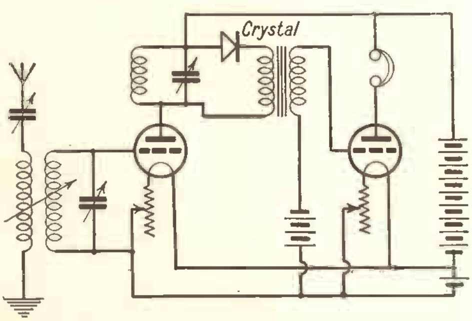


Fig. 6.—SHOWING HOW IT IS POSSIBLE TO HAVE A STAGE OF HIGH-FREQUENCY AMPLIFICATION WITH A CRYSTAL DETECTOR.

Single-valve Circuits

Now let us investigate a whole range of single-valve receivers. In the first place we have the leaky grid detector, as shown in Fig. 9. You are already acquainted with the action of this circuit, as well as that of anode bend rectification shown in Fig. 10. With both circuits you can try any type of tuning circuit you like, both for long and medium wavelengths.

An Interesting Experiment

And here is another experiment for you. Try the leaky grid and the anode bend methods of rectification with a pentode valve as the rectifier. As you can see from Fig. 11, reaction can be used, the latter being another method of amplification, called regenerative amplification, also already explained. I have devoted some considerable time to this circuit and obtained some very interesting results, which I described in *World Radio* a year ago. Fig. 12 shows another method of regenerative amplification, called the capacity reaction method. Here, as you see, the anode of the valve is coupled to the aerial secondary circuit with the help of a variable condenser.

The Armstrong Super-regenerative Circuit

In Fig. 13 we have a typical circuit called the Armstrong super-regenerative

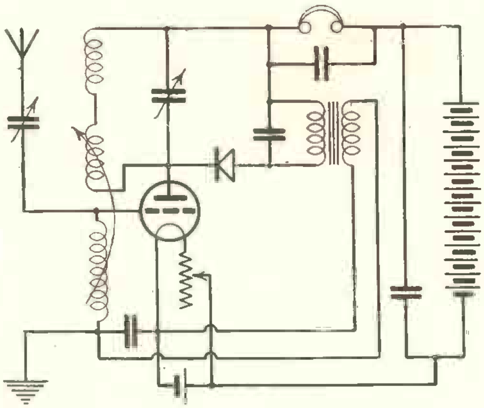


Fig. 7.—AN INTERESTING SINGLE-VALVE CRYSTAL CIRCUIT.

This is a sort of feed back circuit which was very popular a few years ago.

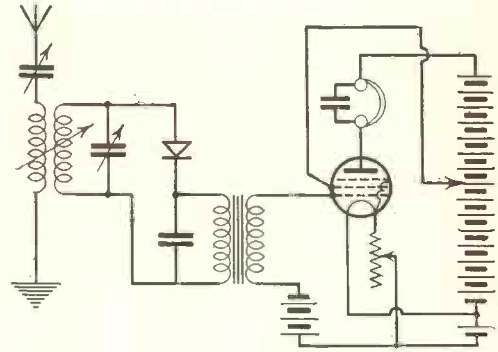


Fig. 8.—A CIRCUIT FOR EXPERIMENTAL PURPOSES.

This is a combination of a crystal and a pentode valve.

circuit. Armstrong is using a reaction circuit, which is intermittently damped so that it cannot break out into oscillations as an ordinary reaction circuit does. With an ordinary reaction circuit, as the coupling between the coils is made tighter and tighter, amplification increases till a howl is heard, and all signals disappear. Armstrong, in order to obtain a large amount of amplification without the howl, introduced a means of providing an intermittent resistance which, at timed periods, damps the oscillations and prevents the disappearance of signals.

The damping circuit is C_4L_4 and C_5L_5, consisting of two coils placed in a two-way coil-holder, the coil L_4 having approximately 1,200 turns and the coil L_5 1,400 turns. These two coils are of the usual plug-in type. The condensers C_4 and C_5 are of 0·001 and 0·002 mfd. capacity respectively.

Tuning the Circuit

The procedure is as follows: The receiver is tuned in the ordinary way as far as the primary and secondary aerial circuits and reaction are concerned. When this is done, the damping circuit is tuned and the coils L_4 L_5 are coupled till oscillations start and then stop. The damping circuit is in action now, and, after a final adjustment for maximum signals all round, the set is ready for work.

Here, again, experiments can be conducted by trying the pentode valve as a detector.

The Flewelling Circuit

Another type of circuit is the Flewelling circuit, shown in Fig. 14. Damping is used again and is carried out with the help of the three condensers of 0·006 mfd.

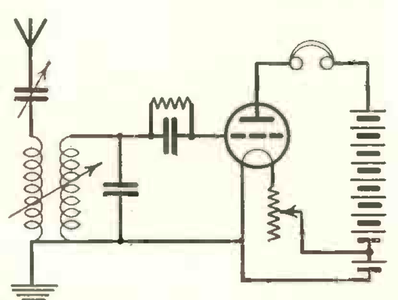


Fig. 9.—CIRCUIT OF SINGLE-VALVE RECEIVER WITH LEAKY GRID DETECTOR.

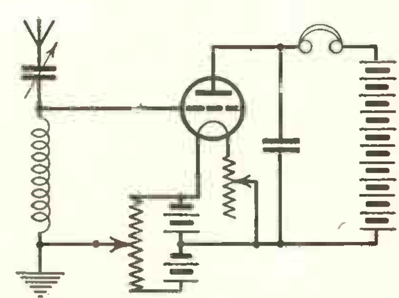


Fig. 10.—CIRCUIT OF SINGLE-VALVE RECEIVER WITH ANODE BEND RECTIFICATION.

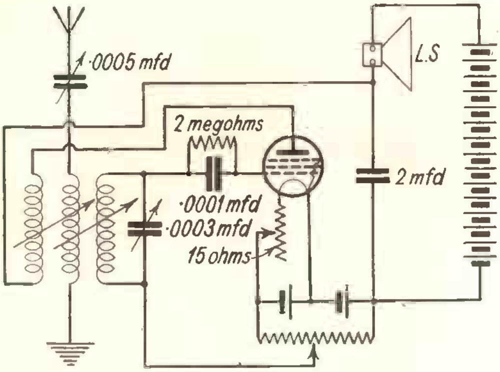


Fig. 11.—ANOTHER INTERESTING EXPERIMENT.

Try the leaky grid and the anode bend methods of rectification with a pentode valve as the rectifier.

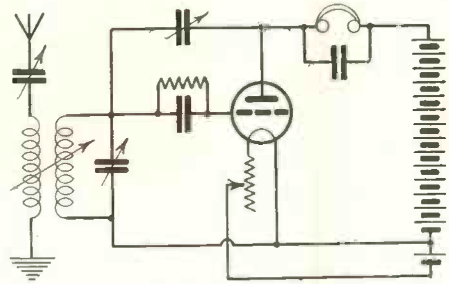


Fig. 12.—CIRCUIT FOR CAPACITY REACTION METHOD.

This is another method of regenerative amplification. The anode of the valve is coupled to the aerial secondary circuit with the help of a variable condenser.

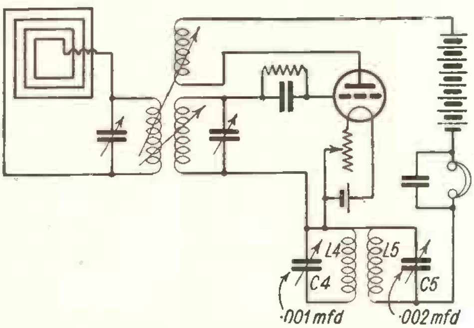


Fig. 13.—THE ARMSTRONG SUPER-REGENERATIVE CIRCUIT.

This is a reaction circuit which is intermittently damped so that it cannot break out into oscillations as an ordinary reaction circuit does.

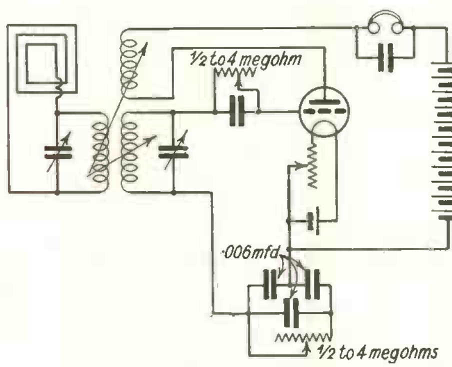


Fig. 14.—THE FLEWELLING CIRCUIT.

Damping is used again and is carried out with the help of the three condensers of 0·006 mfd. capacity. The grid leak is a variable one having limits between ½ and 4 megohms. A variable resistance having the same limits as the grid leak is placed across the three condensers.

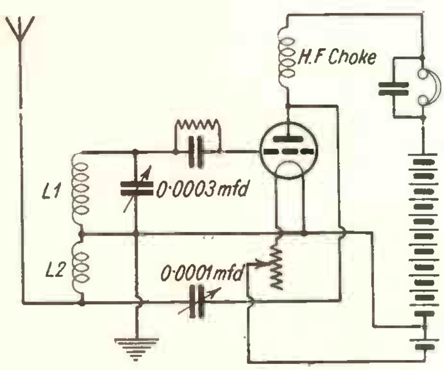


Fig. 15.—THE REINARTZ CIRCUIT.

This circuit was originally designed for short-wave work, and was later adopted to broadcasting wavelengths. This circuit provides a smooth reaction control.

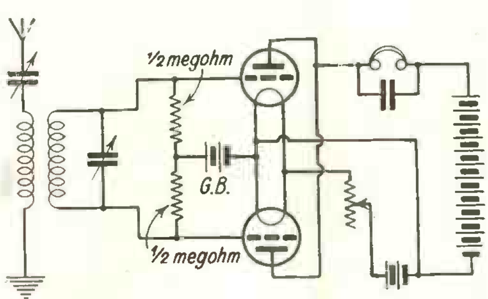


Fig. 16.—A TWO-VALVE CIRCUIT WHICH REALLY WORTH STUDYING.

This is the push-pull rectification circuit

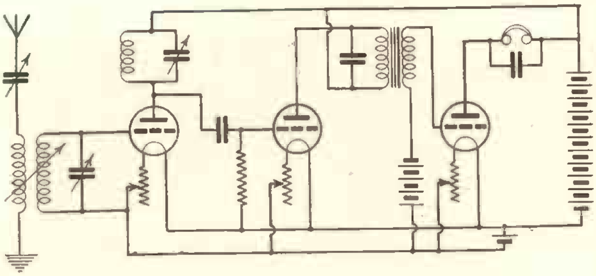


Fig. 17.—A Typical Three-valve Circuit. Here the circuit is shown without reaction.

capacity. You will notice that the grid leak is a variable one, having limits between ½ and 4 megohms. A variable resistance having the same limits as the grid leak is placed across the three condensers. This circuit is peculiar, in that when tuning you first hear a whistle and no signals at all. The two variable resistances are now adjusted till the whistle becomes a high-pitched one. After that the grid leak alone is manipulated till the whistle disappears. The tuning is now completed for maximum signals.

The Reinartz Circuit

The next type of circuit we have to consider is the Reinartz circuit, shown in Fig. 15. This circuit has been originally designed for short-wave work and later adopted to broadcasting wavelengths. The Reinartz circuit provides a smooth reaction control, and is much easier to handle than the two last circuits described above. You will note the H.F. choke in the anode circuit. This consists of an ebonite former 1 inch in diameter having 270 turns of No. 34 S.W.G. insulated wire. The values of the condensers are shown in the diagram. The coils L_1 and L_2, the size of which will depend on the wavelengths you wish to receive, can be placed in parallel planes in fixed single coil holders. Again you should try a pentode valve with this combination.

Try a Pentode Valve in Single-valve Circuits

It is extremely interesting to compare results obtained with all the single-valve circuits described above, and here is some experimenting for you with something definite in view. Do you know that the pentode valve used as a detector with reaction in the usual orthodox way will give loud speaker reception at a range of some fifty miles from the broadcasting station? What will happen in either Armstrong, Flewelling or Reinartz circuits? I don't suppose anybody bothered to try out the new valves with these old circuits. See what you can get.

Two-valve Circuits

In the case of a two-valve circuit we can have the following combinations: one H.F. valve and detector valve; one H.F. valve, a crystal and a L.F. valve; as well as one detector valve and a L.F. valve. Reaction can naturally be used in order to increase the amplification.

Push-pull Rectification Circuit

But here is a two-valve circuit that is really worth studying. This is the push-pull rectification circuit which I mentioned in a previous article and which is shown here in Fig. 16.

Before we come to circuits employing modern valves, let us consider the usual straight circuits made up of three electrode valves so as to get at the elementary essentials of intervalve coupling.

Typical Three-valve Circuit

A typical three-valve circuit is shown in Fig. 17 (without reaction) and Fig. 18 (with reaction). The first valve is a H.F. valve with tuned anode, the second

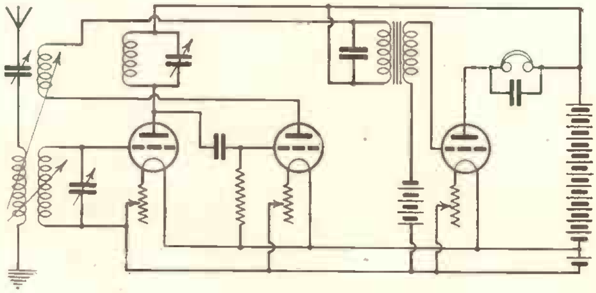


Fig. 18.—A Typical Three-valve Circuit. In this diagram reaction has been added.

valve is a detector valve, which is coupled to the last valve through a L.F. transformer. These are the essential connections, which will remain the same from stage to stage as the number of stages is increased. If you add another H.F. valve (before the detector) you will merely repeat the circuit of the H.F. valve already shown. The same will apply if you introduce another L.F. valve. Thus it is clear that, although a multi-valve circuit appears to be pretty complicated, its complications arise out of mere repetition of intervalve coupling, and when you have analysed one circuit you have analysed every circuit in that particular stage, be it H.F. or L.F.

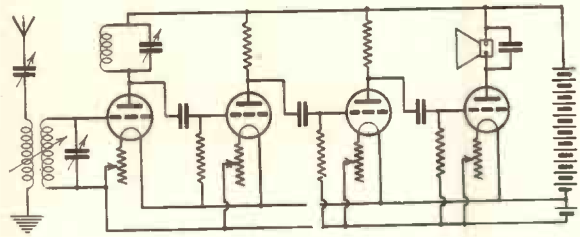


Fig. 19.—VARIATION OF COUPLING IN L.F. STAGES. This shows low-frequency resistance capacity coupling.

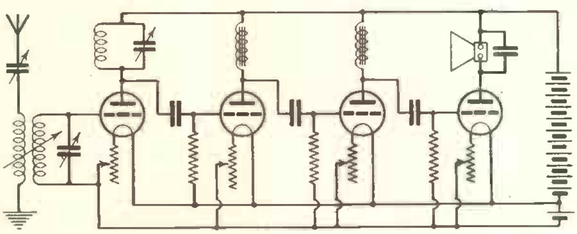


Fig. 20.—VARIATIONS OF COUPLING IN L.F. STAGES. Here we have low-frequency choke coupling.

Variations of Coupling in L.F. Stages

Since the tuned anode is generally used in the H.F. stages, let us consider the variations of coupling in the L.F. stages. These are already familiar to us from our discussion of amplification. In Fig. 19 we have L.F. resistance capacity coupling, in Fig. 20 we have L.F. choke coupling, and in Fig. 21 L.F. transformer coupling. The last three circuits are shown without reaction, which can naturally be used by coupling the reaction coil in the anode circuit of the detector valve, either to the aerial circuit or the first tuned anode circuit. The latter method is shown in Fig. 22.

If you study carefully the modern theoretical diagrams given in this work, you will find that the modern circuits using screened-grid and Pentode valves are following the usual practice, apart from the complications introduced by fixed coils used for dual ranges instead of plug-in coils, etc.

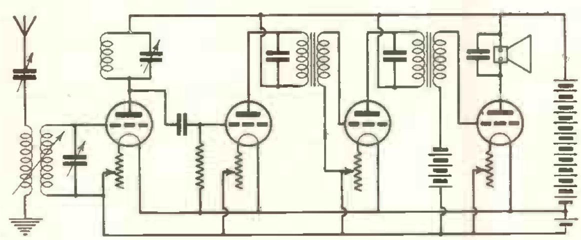


Fig. 21.—VARIATIONS OF COUPLING IN L.F. STAGES. This shows low-frequency transformer coupling.

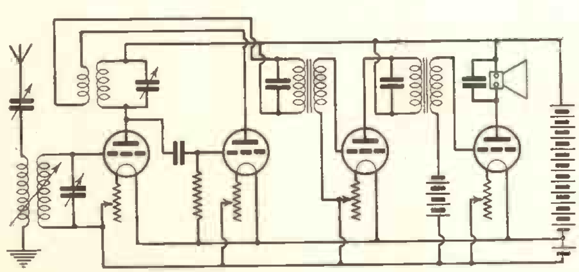


Fig. 22.—HOW REACTION CAN BE ADDED TO THE THREE PREVIOUS CIRCUITS.

The Modern Tuning Circuit

Let us consider this modern tuning circuit. An example is given in Fig. 23, in which Colvern coils are used. The primary aerial circuit is untuned. The

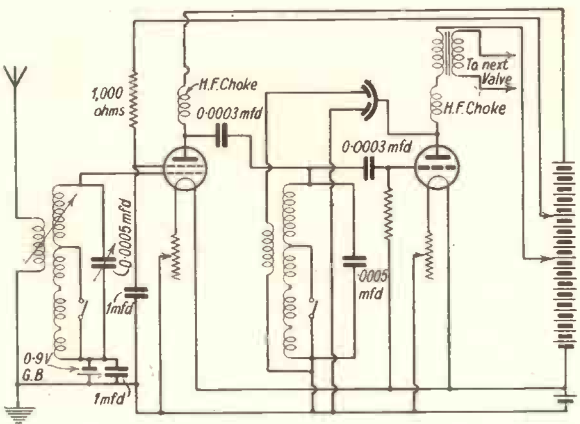


Fig. 23.—A Modern Tuning Circuit. This is a circuit using Colvern coils.

loosely-coupled aerial secondary coils are of dual range with a short-circuiting switch. The coils in the grid circuit of the detector valve are exactly the same as those in the aerial circuit. You will notice that the connections of the screened-grid valve are the usual connections, except the additional lead through a resistance, which drops the H.T. voltage to the screening grid requirements, to the H.T. battery.

Band-Pass Filter

In Fig. 24 we see the complications introduced by a band-pass filter, made up of special Colvern units. The screened-grid valve is of the mains type, which further complicates the circuit.

Four-valve Circuit

In Fig. 25 we see a modern four-valve circuit employing two screened-grid valves, a detector valve and a pentode valve. Compare the difference in the coupling of the last valve in the case of an ordinary three-electrode valve and the pentode valve here shown. The circuits used in short-wave work follow the general principles, and a typical single valve receiver is shown in Fig. 26. Another type is shown in Fig. 27.

The Superheterodyne Receiver

And now let us step over to the last type of circuit which is so much in use now, namely, the superheterodyne receiver. Here we have quite a different method of reception, which consists of mixing local oscillations with those received from a broadcasting station, so that in the end we obtain an intermediate frequency. This is known as the *beat method* of reception.

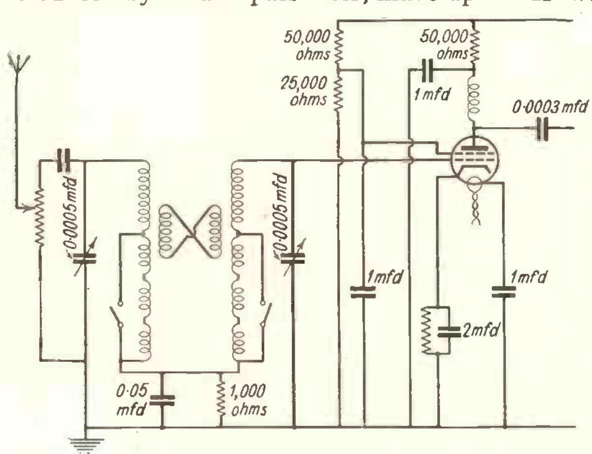


Fig. 24.—Here we see the Complications introduced by a Band-pass Filter, made up of Special Colvern Units.

Vibrations of Two Tuning Forks

If we take two tuning forks having different but close-lying pitches and make them vibrate simultaneously, instead of hearing two separate notes, we shall hear only one note, which will prove to be a combination of the two. Thus, instead of having two frequencies of vibration, we shall have one, and this resultant frequency will prove to be the difference between the two. If one tuning fork is capable of vibrating at, say, 5,000 cycles per second and the other tuning fork will vibrate at 4,000 cycles per second, the resultant beat note will have a frequency of 1,000 cycles per second. This state of affairs is due to the interference of the two sound waves which combine into one wave of a frequency equal to the difference between the two.

What happens when Two Differing E.M.F.'s are Superimposed on the Same Circuit

This sort of thing will happen also in the case of electrical frequencies if we superimpose two differing E.M.F.'s on the same circuit. Suppose we have in our receiving circuit an E.M.F. induced by a wave of 300 metres, which is equivalent to 1,000,000 cycles per second. Suppose from some local source, an oscillator, we impress upon the same circuit another E.M.F. having a frequency of 900,000 cycles per second, then our resultant E.M.F. active in the circuit is 1,000,000 — 900,000, or 100,000 cycles per second. This is equivalent to an E.M.F. induced by a wave of 3,000 metres.

In this manner, with the help of a local oscillator, we can manufacture any resultant E.M.F. we like, and for this reason can design our amplifier for a given band of wavelengths with a much greater precision than it is possible with any other method of reception.

What actually happens in a Circuit employing the Beat Method of Reception

In order to appreciate what is happening, let us consider an actual circuit employing the beat method of reception. This circuit is shown in Fig. 28. The aerial circuit consists of a frame aerial loosely coupled to the grid of the detector valve, which works with the usual leaky grid. In addition to this, we have a coil L_3 which is connected between the secondary aerial circuit and the filament of the detector valve. This coil couples the detector circuit to the circuit of the oscillator valve which manufactures the local oscillations.

The oscillator valve has two coils—one in the anode circuit L_5 and one in its grid circuit L_4. The latter is tuned with the help of a variable condenser C_4. In the first place, we tune in the incoming desired wave in the usual way with the help of the two circuits C_1L_1 and C_2L_2. This being done, we devote our attention to the condenser C_4, which we tune so as to cause the oscillator valve to oscillate at some chosen frequency.

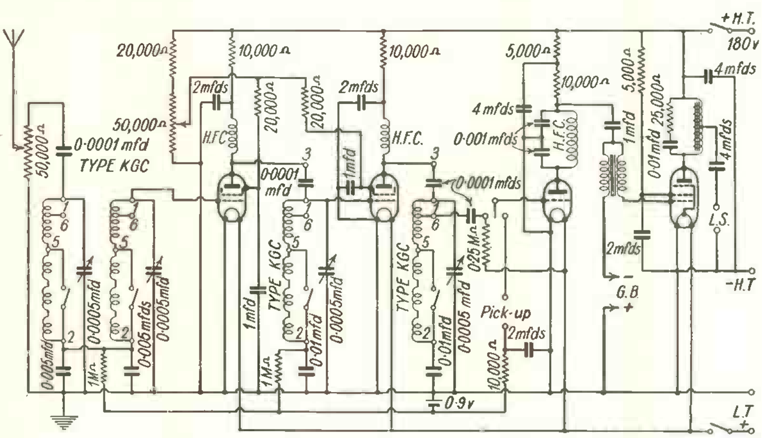


Fig. 25.—A Modern Four-valve Circuit.
Employing two screened-grid valves, a detector valve and a pentode valve.

We will assume that the condenser C_4 is calibrated in frequencies instead of the usual degrees. Let this frequency, as we said before, be 900,000 cycles per second. Let the tuned-in incoming E.M.F. be of a frequency 1,000,000 cycles per second. The 900,000 cycles per second frequency produced in the circuit L_4C_4 is inductively impressed upon the coil L_3, and thus on the grid of the detector valve. The latter will thus have two frequencies impressed upon it, and these two frequencies will combine into one, and we shall have across the grid of the detector valve a resultant E.M.F. of alternating nature having a frequency equal to the difference of the two impressed frequencies, viz., 100,000 cycles per second.

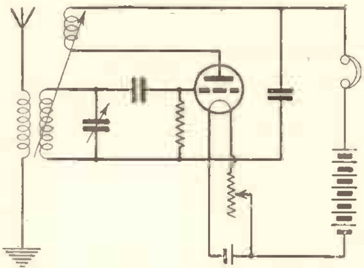


Fig. 26.—A Typical Single-valve Circuit for Short-wave Reception.

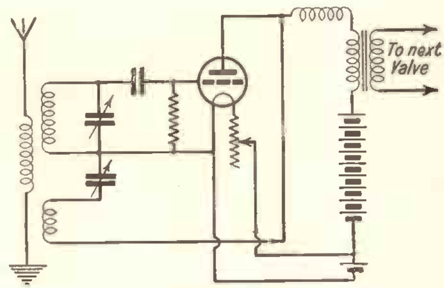


Fig. 27.—Another example of a Short-wave Receiver.

The Characteristics of Modulation are Not altered

Now, the incoming E.M.F. is an alternating E.M.F., which is the result of a modulated electro-magnetic wave, and therefore bears the characteristics of modulation. This modulation is not affected by the arrival of the local alternating E.M.F., whi h is of regular character. You will realise that if we add something regular to something irregular, the irregularity will not be affected and its character will remain the same. In this manner the addition of local regular alternating oscillations to the received modulated oscillations will result in oscillations of a different frequency, but bearing the same modulation characteristics as the incoming wave.

Components of Current

From the point of view of components of current it means that the high-frequency component will have a different frequency, but the low-frequency component will remain the same. The detector valve will deal with the resultant E.M.F. applied to its grid in the usual way, and we shall obtain the same signals as we would obtain with the detector valve alone.

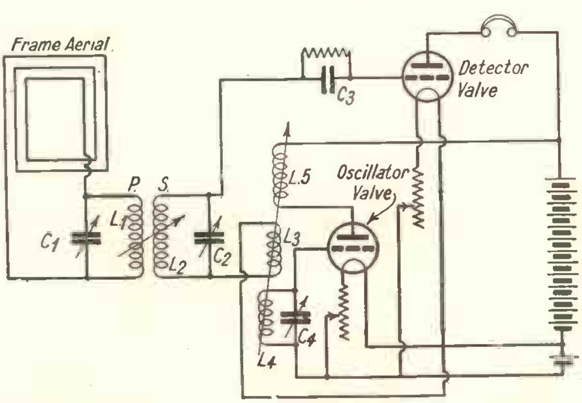


Fig. 28.—An Actual Circuit employing the Beat Method of Reception.

The aerial circuit consists of a frame aerial loosely coupled to the grid of the detector valve, which works with the usual leaky grid.

You will notice that the detector valve deals with a frequency (in our case 100,000 cycles per second) lying far apart from the incoming wave's frequency (1,000,000 cycles per second), and therefore well away from any interfering frequency within the limits of 900,000 cycles per second, which is equivalent to differences in wavelengths from 300 metres and 3,000 metres. Thus, all interference from close-lying stations is eliminated.

Four-valve Superheterodyne

This is the principle of working of the superheterodyne receiver which is shown in Fig. 29. This is a four-valve receiver. At the present moment seven-valve superheterodyne receivers are the order of the day, and they incorporate screened - grid valves of the variable-mu variety. The result, as far as the diagram is concerned, is somewhat complicated, but if you study the circuit closely you will find that it is not as complicated as it looks at first

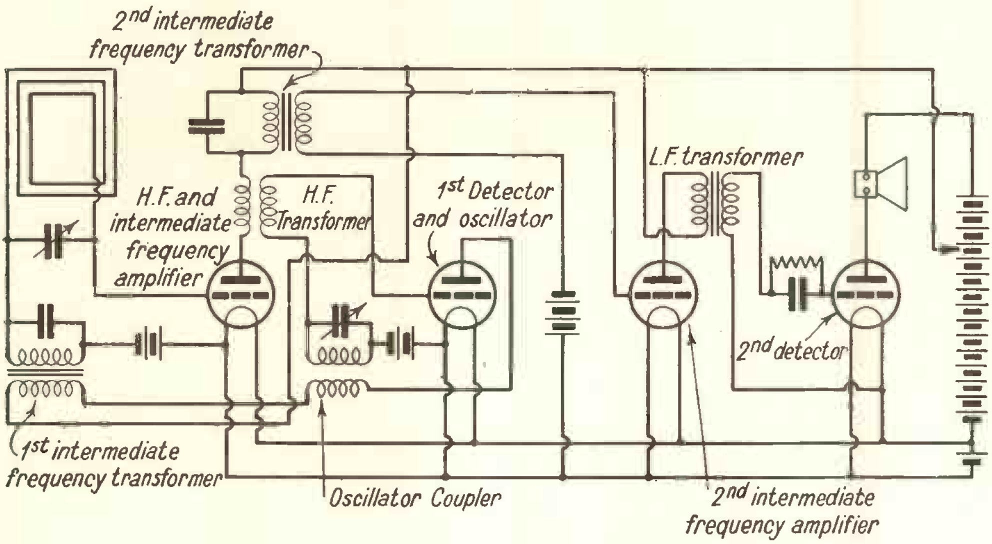


Fig. 29.—A Four-valve Superheterodyne Receiver.

sight. The superheterodyne receiver has been dealt with in detail in this work on pp. 515 to 524, and those interested in this type of circuit are referred to those pages.

The Stenode Circuit

There is a further development of the superheterodyne receiver in the Stenode circuit, which has been dealt with by the inventor, Dr. J. Robinson, on pp. 727 to 731.

There are Comparatively Few Basic Circuits

Thus, as you see, there are comparatively few basic circuits, but the number of variations is apparently without limit.

Once we know the theory underlying the working of each circuit, and from the previous articles we should have this theory at our disposal, it is an easy matter to analyse any new circuit and see how it is made up. Having done this, we can easily follow from stage to stage what happens in each part of the receiver.

When you come to think of it, what is there in an average receiver? Valves, coils, condensers, resistances of several kinds, transformers, chokes, batteries and a loud speaker.

If the function of each component is clear, there should be no difficulty in appreciating the cycle of events in each part of the receiver.

Having gone this far, let us take another step forward in the next section towards consolidating our knowledge of the science of radio, and review the units used in our electrical measurements. Let us also see how these units are related to other units, how they are defined, and how they are determined. Having done this, we shall be able to discuss the use of measuring instruments and their application in modern receivers.

QUESTIONS AND ANSWERS

Name Three Basic Circuits for Wireless Reception

(1) The Armstrong super-regenerative circuit.
(2) The Flewelling circuit.
(3) The Reinartz circuit.

Describe briefly the Armstrong Super-regenerative Circuit

This is a reaction circuit which is intermittently damped so that it cannot break out into oscillations as an ordinary reaction circuit does. In order to obtain a large amount of amplification without the howl that results in an ordinary reaction circuit, a means of providing an intermittent resistance is introduced which, at timed periods, damps the oscillations and prevents the disappearance of signals.

Describe briefly the Flewelling Circuit

In this circuit damping is used again and is carried out with the help of three condensers of 0·006 mfd. capacity. The grid leak is a variable one having limits between ½ and 4 megohms. A variable resistance having the same limits as the grid leak is placed across the three condensers. This circuit is peculiar in that when tuning you first hear a whistle and no signals at all. The two variable resistances are now adjusted until the whistle becomes a high-pitched one. After that the grid leak alone is manipulated until the whistle disappears. The tuning is now completed for maximum signals.

Describe briefly the Reinartz Circuit

This circuit was originally designed for short-wave work and later adopted for broadcasting wavelengths. It provides a smooth reaction control. A high-frequency choke is used in the anode circuit.

Is it possible to obtain Loud Speaker Reception using only One Valve ?

Yes. By using a pentode valve as a detector with reaction in the usual orthodox way it is possible to obtain loud speaker reception at a range of some fifty miles from a broadcasting station.

Name Three Variations of Coupling in Low-frequency Stages

(1) Low-frequency resistance capacity coupling.

(2) Low-frequency choke coupling.

(3) Low-frequency transformer coupling

Describe briefly how a Modern Tuning Circuit is made up

The primary aerial circuit is untuned. The loosely-coupled aerial secondary coils are of dual range with a short-circuiting switch. The coils in the grid circuit of the detector valve are exactly the same as those in the aerial circuit.

What is the Principle of the Super-heterodyne Receiver ?

The principle of the superheterodyne receiver consists of mixing local oscillations with those received from a broadcasting station so that an intermediate frequency is obtained. This is also known as the beat method of reception.

Why is a Superheterodyne Circuit very selective ?

Because in this circuit the detector valve deals with a frequency far apart from the incoming wave's frequency and therefore well away from any interfering frequency.

HOW TO USE THE VALVE TESTER

By H. F. J. BUTLER

Fig. 1.—A Quick Method of Testing the Grid Bias Voltages of the Metallised Valves in the Marconiphone Model 256 Superheterodyne.

THIS testing set (described and illustrated on pp. 279–290 and 355) is invaluable to the service engineer, because it provides a rapid means of fault location in commercial and home-constructed receivers. It allows the examination of the working of most receivers without having to remove the chassis from the cabinet.

Testing a Marconiphone Model 256

The Marconi seven-valve superheterodyne is taken as an example to show the methods of checking a receiver with the testing set. Suppose a fault has developed in the receiver, and, as a consequence no signals are received, although a very faint mains hum in the speaker indicates that some part of the set is working.

Procedure in Testing

Remove the back of the cabinet and switch the set on. Preliminary tests are then made before removing the valves. An aerial and earth is connected and the set is tuned, by means of the dial markings, to the local station with the volume control fully advanced. Each valve is then slightly rocked in its holder to test the contact of the valve pins in the sockets. This fault is common in older sets, where the valves have been frequently removed and replaced by an inexperienced person.

Rapid Test of Bias Voltages

Figs. 1 and 2 show how the grid bias voltages of all the receiving valves can be tested without the necessity of removing the valves. Fig. 1 shows how the bias

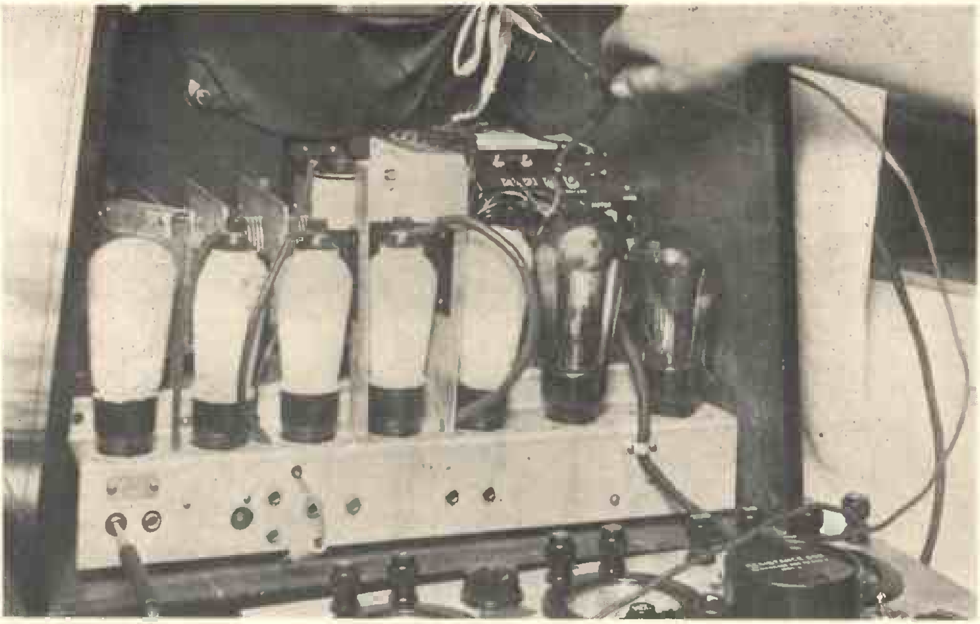


Fig. 2.—Testing the Grid Bias Voltage of the PX4 Output Valve of the Marconiphone 256.

voltage of the first five valves is tested. This is done with the high resistance voltmeter of the testing set. A pair of testing prods are connected to the 50-volt range

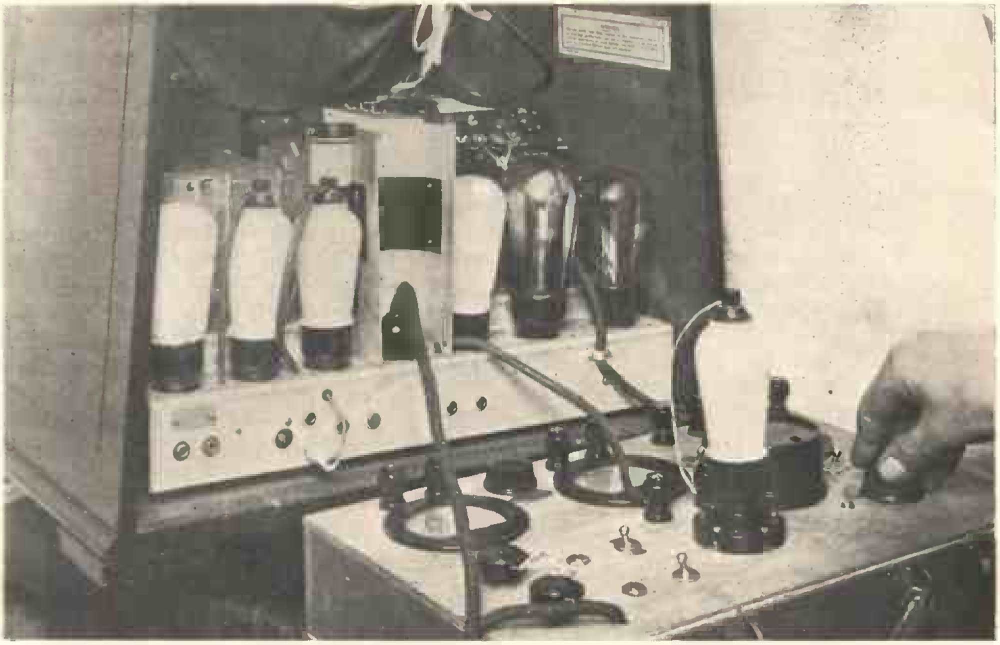


Fig. 3.—Taking Measurements on the I.F. Amplifier Valve of the Marconiphone Model 256, with the Aid of the Testing Set.

Fig. 4.—Testing the Detector Valve of the Two-stage Set described on p. 841.

of the instrument. The negative voltmeter lead is plugged into one of the earth sockets of the receiver chassis, while the positive spike is touched on each of the metallised valves in turn, as shown in Fig. 1. These tests give the true value of the bias voltages, because the metallised surface of the valves is connected to the cathodes, while the bias voltages in this receiver are obtained by resistances between the cathodes and earth.

Testing the Volume Control

When the volume control is varied the grid bias voltages of the first four valves varies also. The proper working of the volume control can be tested by measuring the grid bias values at the same time as the volume control knob is varied from maximum to minimum. The readings which are obtained in this way should tally with the values given in the table.

Testing Bias of Output Valve

The output valve, a Marconi PX4, is located second from the right, as seen in Fig. 2. This is a directly heated triode valve having a grid bias of 37 volts. This voltage is measured as shown in Fig. 2. The 50-volt scale of the meter is used, as for the tests on the metallised valves, with the negative spike in the earth socket. The positive testing prod is touched on the arm of the 20-ohm potentiometer, which is located on top of the mains transformer. This potentiometer is not for adjusting the grid bias of the output valve, but for obtaining the electrical centre of this valve filament. Its adjustment should not therefore be altered.

Testing Valves

The individual voltage and current readings of each valve are taken in the following way :—

With the receiver switched off, remove the extreme left-hand valve and insert it in the valve holder of the testing set. Some care must be taken when removing valves from their holders. Usually a valve will come out easily if it is pulled by the base. When the valve is less accessible or is tight in the holder, it is removed by levering out with a screwdriver. After transferring the valve to the testing set, the five-pin plug of the tester is inserted

TABLE OF READINGS OBTAINED WITH A MARCONIPHONE MODEL 256

Valve.	Location.	Milliamp. Readings.			Voltmeter Readings with Switch at:			Switch M or B.
		Jack 1.	Jack 2.	Jack 3.	1.	2	(Grid Bias) 4.	
MH4 Oscillator.	Extreme left.	—	Radio, 2–6 Gram., 0	Radio, 2–6 Gram., 0	—	Radio, 50–70 Gram., 0	Radio, 3–7 Gram., 0	M
MS4 1st Det.	Second from left.	Radio, ·3–·6 Gram., 1–4	·1	Radio, ·4–·7 Gram., 1·1–4·1	190–260	Radio, 50–80 Gram., 57–98	Radio, 3–7 Gram., 2·5–6·5	M
VMS4 H.F. Amp.	Third from left.	Radio, 1·7–0 Gram., 2–0	Radio, 5·5–0 Gram., 7–0	Radio, 7·2–0 Gram., 9–0	190–225	Radio, 51–42 Gram., 57–45	Radio, 2–45 Gram., 2·5–60	M
VMS4 I.F. Amp.	Centre.	Radio, 1·7–0 Gram., 2–0	Radio, 5·5–0 Gram., 7–0	Radio, 7·2–0 Gram., 9–0	190–225	Radio, 51–42 Gram., 57–45	Radio, 2–45 Gram., 2·5–60	M
MH4 2nd Det.	Third from right.	—	Radio, ·9 Gram., 2·2	Radio, ·9 Gram., 2·2	—	195	Radio, 3 Gram., 1·7	M
PX4 Output.	Second from right.	—	50	—	—	260	37	B
U12 Rectifier.	Extreme right.		Do not attempt to measure.					

in the empty valve holder of the receiver. The receiver is switched to radio with the volume control fully advanced.

Before switching on the receiver to test, make sure that the milliammeter switch is set to the 150-milliampere range and that the voltmeter 500-volt multiplier is in circuit. Everything is now set for testing the valve. Switch on the receiver and adjust the voltmeter selecting switch to position 2, with the milliammeter plug in Jack 2. As the receiver is switched on, the voltmeter needle will gradually swing over to about 250 volts, and as the indirectly heated valves warm up the voltage reading drops to 50 at the same time as the milliammeter needle rises to read 2 milliamperes if all is in order.

The milliammeter switch is now shifted to the 7·5 range, so that the current may be read more accurately. The meter in the centre of the tester panel should read 3·75–4 volts if the correct A.C. voltage is reaching this valve.

The grid bias is now measured by switching the voltmeter five-point switch to position 4. Now switch over the D.P.D.T. switch below the voltmeter. The voltmeter will now read the bias of the oscillator valve on the 50-volt scale. The correct bias for this valve with the volume control fully advanced is 3 volts, as shown in the table.

Verify the Transformer Tapping

If the A.C. voltmeter in the centre of the tester panel reads outside the limits of 3·75–4 volts, it is probable that the transformer primary tapping is wrongly adjusted. These tappings are clearly marked on the transformer terminal block and are easily verified.

Fig. 5.—BESIDES SET TESTING, THE INSTRUMENT CAN BE USED FOR A NUMBER OF ORDINARY TESTS.

Here we see a battery being tested by the use of the top row of meter terminals as shown.

Testing a Screened-grid Valve

Fig. 3 shows the measurements being taken on the screened-grid intermediate-frequency amplifier valve of the Marconiphone 256. The flexible lead, which is normally connected to the top of the valve, is connected to the H.T. terminal on the tester, while a lead is wired between the valve terminal and the anode terminal on the tester. With the milliammeter plug in Jack 1, and the voltmeter switch in position 1, the readings of anode current and voltage are obtained simultaneously. The screen voltage and current are now measured by transferring the plug and voltmeter switch to No. 2 positions. The anode current plus the screen current is measured by plugging into No. 3 Jack with a spare plug in No. 4 Jack.

The grid bias values, as shown on the valve tester with the valves in position on the test set, are reasonably accurate for this receiver, because none of the grid circuits contains a high resistance.

Testing Pentode Valves

More thought must be exercised when testing pentode valves, because there are three distinct types of pentodes. The indirectly heated pentode has a terminal on the base. This terminal is connected to the control or auxiliary grid of the valve. Thus the switch and jack positions 1 give the control grid readings, not the anode values, as with a screened-grid valve. The battery pentode is made in two types. The first type has a five-pin base with the centre pin forming the control grid connection, while the second type has the usual four-pin base of the battery valve with a terminal on the base to provide the control grid connection. The various switch and plug positions for taking measurements on all types of A.C. mains and battery valves is given on p. 290.

When testing a 4-pin battery pentode valve, the flexible lead of the receiver, which is normally connected to the terminal on the valve base, is extended to the H.T. terminal of the testing set, while the base terminal is wired to the " A " terminal on the panel. This procedure is similar to that of testing a screened grid valve. The mains or indirectly heated pentode is treated in the same way.

The testing of a 5-pin battery or directly heated pentode is different from that of the other types. The voltmeter switch in position 1 gives no reading. Position 2 gives the anode voltage, while 3 gives the screen or control grid volts. The control grid current is measured by plugging the milliammeter plug into Jack 4, with a spare plug in Jack 3.

Tests on Triode Valves

Triode valves are the simplest to test, because only three measurements are taken. These are the anode volts, anode current and grid bias volts. Fig. 4 shows the testing of the detector valve of the two-stage receiver described on p. 841. This valve has an anode voltage of 90–100 with an anode current of 4 milliamperes. The output valve of this receiver affords an example of inaccurate grid bias readings. When the output valve is plugged into the tester and the switches are adjusted so that grid volts are indicated on the right-hand instrument, a reading of only 6 volts is obtained. This is because the meter current flows through R4 (Fig. 6, p. 845), which counteracts a proportion of the bias voltage. At the same time it will be noticed that the anode milliamperes has risen, as indicated on the left-hand instrument, to 60 milliamperes. This shows that the bias resistance is at least working. To obtain a more accurate measurement of the grid bias voltage in a receiver, where there is a similar high resistance in the grid circuit, the bias is measured across the biasing resistance without removing the valve from the receiver. This is done with the aid of the testing prods connected to the external terminals of the high resistance voltmeter. Even this method of measuring automatic grid bias is not free from error, because the meter reduces the value of the bias resistance slightly. The inaccuracy is, however, very slight on power valve measurements, provided that the highest possible voltmeter range is used, so as to limit the shunting effect of the voltmeter.

Tests on Battery Sets

The testing set is designed so that it is suitable for measurements on both mains and battery driven receivers. In order to obviate the use of two valve holders on the test set panel, a small switch is provided to make the necessary change in connections when battery or directly heated valves are being tested. This switch, marked " M " and " B," is located on the right of Jack 2. (See p. 279.)

When the testing set is to be used for taking measurements on battery receivers, this switch is set to " B " position and the 5–4-pin adapter is used on the cable plug to allow it to be inserted into valve holders which will not accommodate the centre pin of the 5-pin plug. If one attempts to take measurements on a battery set with the change over switch in the " M " position, no harm results, but no readings of H.T. and grid bias are obtained, because the negative pole of the 3-range voltmeter is disconnected. In the same way if readings are taken on indirectly heated valves with the switch in the " B " position, no harm is done, but in this instance readings are obtained which are inaccurate, because the voltage is being measured across the anode or grid and heater instead of across the anode or grid and the cathode.

Effect of Cable Capacity

The cable, which forms the connecting link between the testing set and the receiver, naturally adds a certain amount of capacity between the electrodes of the valve, on test in the valve holder of the test set. This does not upset the voltage and current readings of the valves, but causes a cessation of signals when certain valves are on test. This applies to any valve having a tuning coil in its circuit because the added capacity will detune the circuit of the valve on test. The valves affected in this way are high frequency amplifiers, detectors, and oscillator valves of superheterodyne receivers. The signals are not materially affected when testing low frequency and output valves unless the cable is unduly long.

Using Meters Separately

A row of terminals is provided on the top of the testing set to enable the instruments to be used for individual tests. Fig. 5 shows the 250 volt range of the high resistance voltmeter being used for testing a high tension battery. The same meter is used for testing low tension batteries, except that the 10 volt range is used.

DESIGN AND CONSTRUCTION OF A POWER AMPLIFIER

By A. E. WATKINS

AMONGST radio apparatus a high-quality amplifier is one of the most useful pieces there is, for it is readily assembled and possesses lasting utility. Once constructed it will not go out of date, as it is the nucleus around which we may build either an electric gramophone or radio receiver, it being only necessary to add either a pick-up for gramophone amplification or a detector and, if required, H.F. stages for a high-quality radio.

Output of the Amplifier

Unlike a complete radio receiver, which is a specialised apparatus and in some cases of only a temporary interest, the components for the amplifier are an invaluable acquisition, for the L.F. amplifier has so many uses. It can be used for public-address systems, gramophone amplification or radio amplification. By using the components mentioned, the amplifier will have a fairly flat overall output from 50 to 8,000 cycles, falling off gradually to about 15,000 cycles.

Specification

Variable input to first L.F. valve followed by two stages of L.F. amplification push-pull, 24 watts anode dissipation. All A.C. operation, automatic grid bias.

Should it be necessary to operate this amplifier from D.C. mains or accumulators, this can be done conveniently by means of an M.L. converter, this being the most satisfactory manner of operating an amplifier of this description, for it requires 500 volts at 120 m.a.

Advantages of Push-pull Output

For high-quality output for operating one or more large moving-coil loud speakers, push-pull output is undoubtedly the most satisfactory for the following reasons :—

(1) It greatly reduces the harmonic caused by curved characteristics.

(2) It gives at least double the power of one valve because of the reduction of harmonics.

(3) The arrangement enables the D.C. magnetisation due to the steady plate current of the valve to cancel each other out, and therefore there is less chance of distortion due to high D.C. magnetisation of the iron core.

(4) The signal passes from the valve plate to valve plate ; prac-

LIST OF COMPONENTS

Mains transformer, output 500-500, 7·5-volt, 4-volt (*Varley EP24*).
Smoothing choke, 45 henries at 120 m.a. (*Parmeko*).
Output filter choke, 30 henries at 50 m.a., centre tap (*Parmeko*).
Push-pull transformer AF3C (*Ferranti*).
Condensers, 800-volt working—
- C. 1, C. 2, 1 mfd. (*T.C.C.*).
- C. 6, C. 7, C. 9, 4 mfd. (*T.C.C.*).
- C. 3, C. 4, C. 5, C. 8, 2 mfd. (*T.C.C.*).
- C. 10, C. 11, ·0003 mfd. mica.
- C. 12, C. 13, ·01 mfd. (*T.C.C.*).

Resistances—
- R. 1, 1,000 ohms, wire wound (*Watmel*).
- R. 2, R. 3, 100,000 ohms, wire wound (*Watmel*).
- R. 4, R. 5, 25,000 ohms, wire wound (*Watmel*).
- R. 8, 15,000 ohms, wire wound (*Watmel*).
- R. 9, 2,500 ohms, to carry 150 m.a., wire wound (*Watmel*).
- R. 10, 50,000 ohms, Type 3. Potentiometer (*Watmel*).
- R. 7, 600 ohms, Type 1. Potentiometer (*Watmel*).
- R. 6, 15 ohms, Type 3. Potentiometer (*Watmel*).
- H.F. choke, Type D.X. 3 (*Watmel*).
- Input and output terminal blocks (*Belling and Lee*).
- Mains plug (*Belling and Lee*).

Valves—
- V. 1, 354 V. (*Mullard*).
- V. 2 and V. 3, P.X.4, for push-pull (*Osram*).
- U. 8 Rectifier (*Osram*).

tically none passes through the H.T. supply, hence there is less chance of feeding back to previous stages with consequent self-oscillating or motor-boating.

(5) Any ripples in the H.T. supply, grid bias or filament supply do not appear in the transformer or speaker, since they affect each half of the winding by equal amounts in the opposite directions.

Power Control

High-quality output has been the aim in the design of this amplifier, but this does not mean that the power is overwhelming, for the input can be controlled by the potentiometer in front of the first L.F. valve, but the vastly different relative amplitudes of voltage can be accommodated by the grid and, due to the generous output, the valves may be under-run so that effect of the curvature of the characteristics becomes insignificant, while considerable power output is available when occasion demands.

The Circuit Diagram

Before describing the construction, it would be as well to look at the circuit diagram, which is quite straightforward and contains no complications. Should the reader wish, the values of the various resistances may be varied to suit other makes of valves. This, of course, particularly applies to the grid-bias resistances and the voltage-dropping resistance in the anode circuits, for the resistance of the transformers and chokes will remain constant.

Calculating the Value of the Resistances

The calculation of the value of the resistances is very simple. First, we must refer to the valve maker's data. Take, as an example, the P.X.4. The maximum anode voltage is 250 with an average anode current of 48 milliamps. with a grid-bias voltage 34. Now 250 and 34 equal 284. Therefore, the remainder of the voltage from the rectified H.T. current must be dropped between the smoothing choke, anode choke or transformers, and any resistances in the plate circuit.

Output after Smoothing

Using a rectifier valve of the Osram

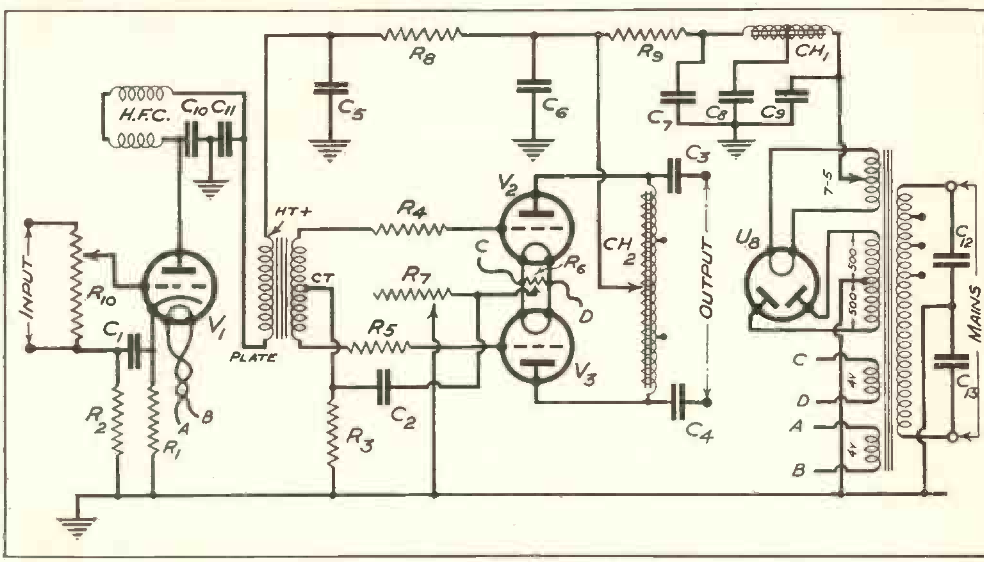


Fig. 1.—Circuit Diagram for Power Amplifier.

The values of the resistances and condensers are as follows: R.1, 1,000 ohms (20 m.a.); R.2, 100,000 ohms; R.3, 100,000 ohms; R.4, 25,000 ohms; R.5, 25,000 ohms; R.6, 15 ohms; R.7, 600 ohms (150 m.a.); R.8, 15,000 ohms (20 m.a.); R.9, 2,500 ohms (150 m.a.); R.10, 50,000 ohms; C.1 and C.2, 1 mfd.; C.3 and C.4, 2 mfd.; C.5, 2 mfd./800 volts; C.6 and C.7, 4 mfd./800 volts; C.8 2 mfd./800 volts; C.9, 4 mfd./800 volts; C.10 and C.11, ·0003 mfd.; C.12 and C.13, ·01 mfd.

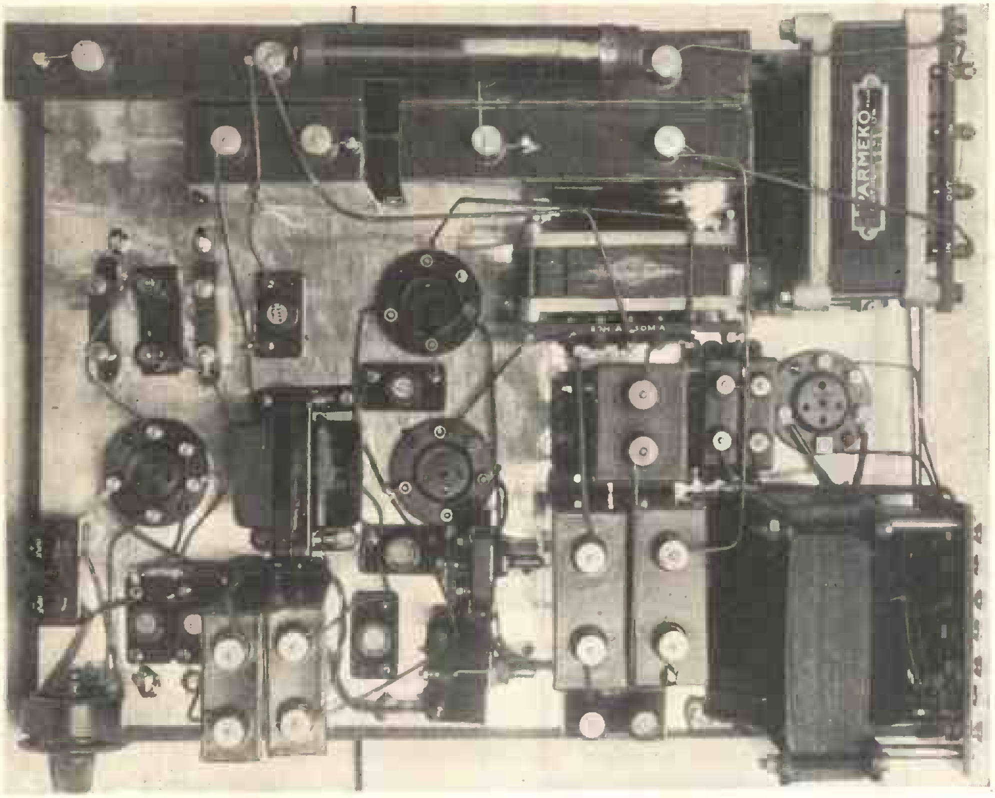


Fig. 2.—PLAN SHOWING THE ARRANGEMENT OF COMPONENTS AND WIRING.
Note how simple the wiring is, due to earthing direct to metal baseboard covering.

U.8 type with 500 volts on each anode, the output after smoothing will be approximately 475 volts at 120 milliamps., and it is from this voltage that the calculations for the resistances in the various circuits are made. In making these calculations, it is as well to work backwards, that is, from the output valves, as any resistance in the anode circuit of the output valve is usually used as part of the resistance for the earlier valves. The resistance of the filter choke has a total of 370 ohms. This is the Parmeko filter choke, Type F. As only half of this choke is in each plate circuit of the P.X.4 output valves, the resistance is divided by two and each side of the choke will carry approximately 50 milliamps. and will, therefore, only drop 9 volts, which need hardly be taken into consideration.

Resistance with Tapping Points

Using the P.X.4 valves, therefore, we will have to drop another 191 volts in the resistance. As this resistance will also be carrying the anode current of the first L.F. valve, it will be passing, approximately, 101 milliamps. with a 345 Mullard valve which is being used. As the first valve may be varied to suit the conditions, it would be advisable to have a larger resistance with tapping points so that it can be altered according to the conditions.

When passing 101 milliamps. the resistance will be, approximately, 2,000 ohms; therefore, the resistance is adjustable and can be adjusted to suit almost any valve which it may be desired to use, either in the first amplifier or the principal output stage.

The author will be pleased to supply a

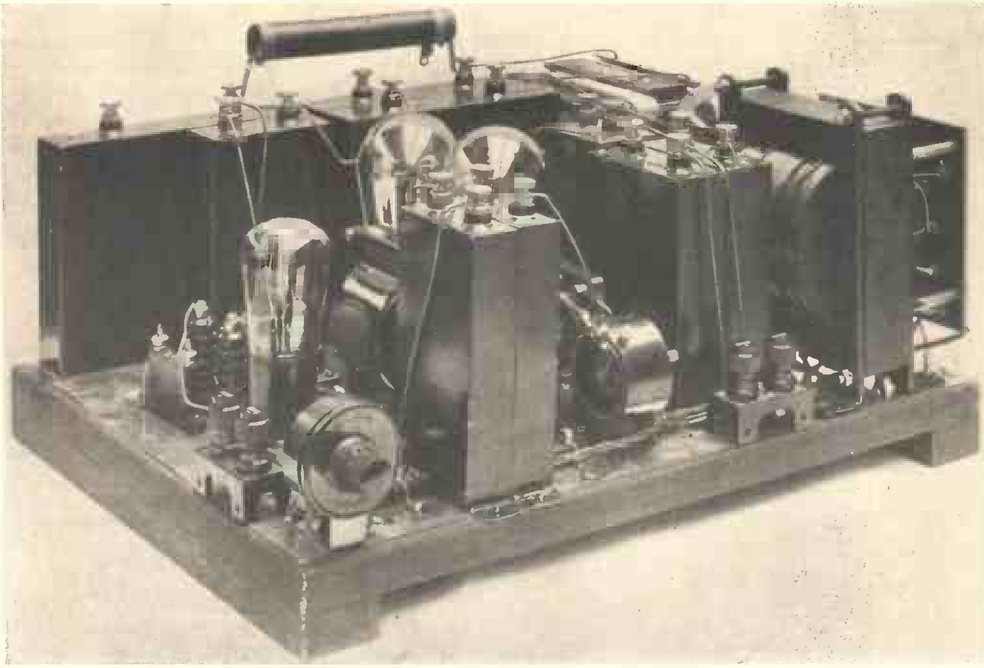


Fig. 3.—FRONT VIEW, SHOWING THE VOLUME CONTROL ON THE LEFT.
The first L.F. valve is just behind.

simple line chart for easy calculation of resistances to any reader who writes to him c/o the Editor.

The Circuit Described in Detail

We will now describe the circuit in detail, beginning from the input.

First, there is a 50,000-ohm potentiometer placed between the grid and cathode of the first valve, and is of the Watmel Type 3 non-inductive.

In the cathode lead are the grid-bias resistances and the by-pass coupling condensers. In the anode circuit it will be noticed that an H.F. choke is included with two by-pass condensers ·0003 mfd. While it is not essential to use this H.F. choke when the amplifier is used purely as a radio gramophone, it is nevertheless an advantage when it is used for radio reception, as it effectively prevents any H.F. current being transferred to the output valve. Secondly, if the first valve was used as a detector, reaction could be used from the plate.

Transformer

The transformer is a Ferranti AF3C push-pull, and will effectively carry the anode current necessary for the first valve.

In circuit with the primary is the necessary voltage dropping resistance of 15,000 ohms and by-pass smoothing condenser ·2 mfd.

In each output grid lead from the transformer are two resistances, the value of these being approximately 25,000 ohms, any value near this being perfectly satisfactory. They are included to prevent self-oscillation if the valves are slightly defective or soft.

How the Anodes of the Valves are Coupled

The anodes of the valves are coupled by an output filter choke, but this may be replaced with a suitable push-pull output transformer if preferred, or, in some cases where the speaker itself is fitted with an output transformer, it may be connected direct. In the case of high-resistance wound speakers, the output choke is the best system to use, as owing to the tapping it can be adjusted to suit the impedance of the speaker, but it must be remembered that each tapping must be adjusted so that there is equal balance between the centre points.

H.T. Smoothing Choke

The H.T. smoothing choke is wound in two sections, being joined together in the centre and the condenser coupled between earth (in some cases this condenser is better left out). This in effect gives two smoothing chokes in series.

Mains Transformer

The mains transformer is the Varley E.P.24, which is easily adapted to any supply, for the input voltage of 200 to 250 is in steps of 10 volts. The output for the valve rectifier is 500 plus 500 volts, while there are various tappings to suit the filaments of the valve and also the rectifier valve. This, therefore, gives a very flexible unit suitable for all conditions of supply, but for voltages below 200 a special transformer will be needed.

Smoothing Condensers

It is most important that the smoothing condensers used in the anode circuit of this amplifier should have a high-voltage break-down test and 800 volts working condensers are chosen, for on certain parts of the circuit we have a steady voltage of approximately 500 volts, and at times surges will be set up greatly in excess of this voltage; also, the two output condensers should be of the high-voltage type, as between these condensers and earth we have a high voltage, and a short circuit in the speaker leads may cause a breakdown of these condensers unless they can withstand at least 800 volts.

Decoupling Condensers

The decoupling condensers in the grid-bias circuit will be perfectly satisfactory if they are capable of standing 250-volts working, but the two condensers C. 11 and C. 10 should be of mica dielectric.

In the output valve filament circuit a resistance across the filament will be noted. This is to adjust the centre point and to reduce hum.

Adjustable Grid-bias Resistance

The resistance R. 7 is adjustable so that the correct grid bias may be obtained. By making this adjustable, the anode current can be quickly adjusted to the correct values, if any other type of valves is fitted in an emergency. The value of

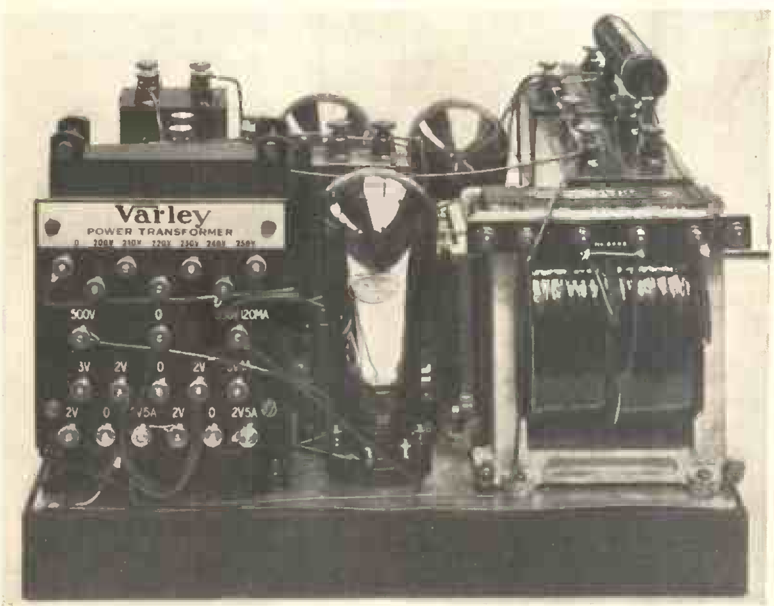


Fig. 4.—End View, showing Mains Transformer, Rectifying Valve and Smoothing Choke.

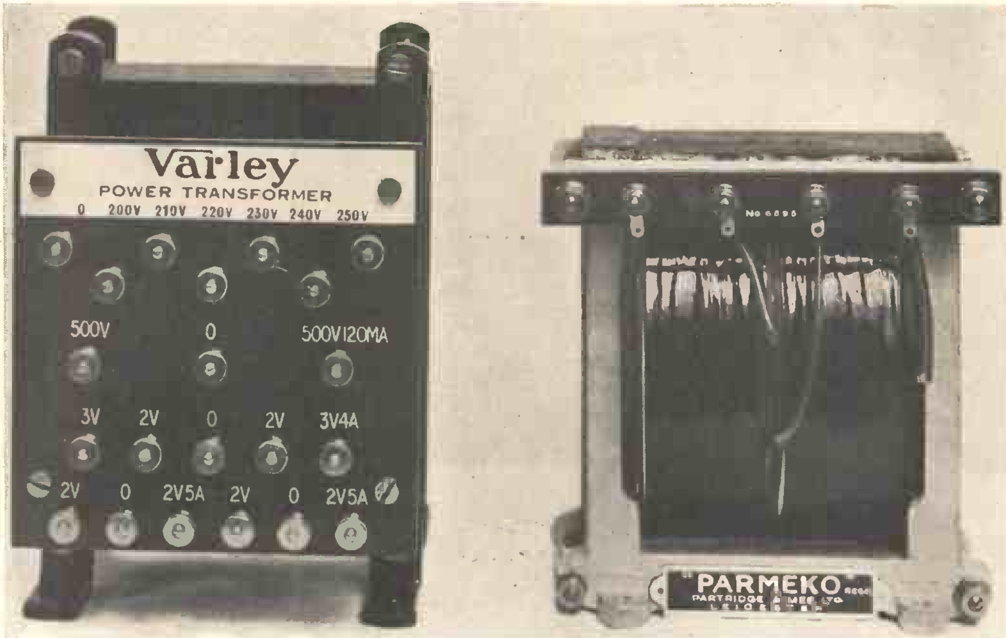


Fig. 5.—THE MAINS TRANSFORMER AND SMOOTHING CHOKE.

The mains transformer has multiple tappings to suit the conditions of power supply. The smoothing choke is wound in two sections, the centre terminals being bridged and, in the case of this amplifier, connected to a 2-mfd. condenser.

this resistance is in excess of that required for the correct grid-bias voltage for the valves chosen, but should a valve be fitted which consumes lower anode current, it can readily be adjusted, for the less the anode current the greater the resistance usually required to produce the necessary voltage for proper bias.

Valves should be Matched

When ordering valves for push-pull output, it is advisable to tell the makers that they are required for this purpose. They will then send matched valves, which greatly improve the working, as otherwise the grid bias on each filament must be separately adjustable and we should then require a transformer with two secondary windings, but this is not necessary if the precaution is taken in ordering correctly matched valves.

CONSTRUCTING THE AMPLIFIER

Having now described the component parts of the amplifier in detail, we will proceed with the construction. This has been kept as simple as possible.

All the components are mounted upon a baseboard lined with metal so as to earth every component, which is a very necessary precaution with high-voltage amplifiers.

Those who wish may construct a metal cover completely to house the whole instrument, but ventilation holes should be made in the sides to allow for the free circulation of air for valve cooling, as the valves will get appreciably warm when in use. The cover must make effective earth contact with the baseboard.

Baseboard Size

A convenient size for the baseboard is 13 inches by 17 inches by 1 inch with two battens along each end securely screwed so as to prevent warping. Heavy components, such as the transformers and smoothing chokes, should be bolted through the baseboard, for wood screws are not sufficiently strong to carry these heavy components. The lighter pieces, such as condensers, valve holders and resistances, may be

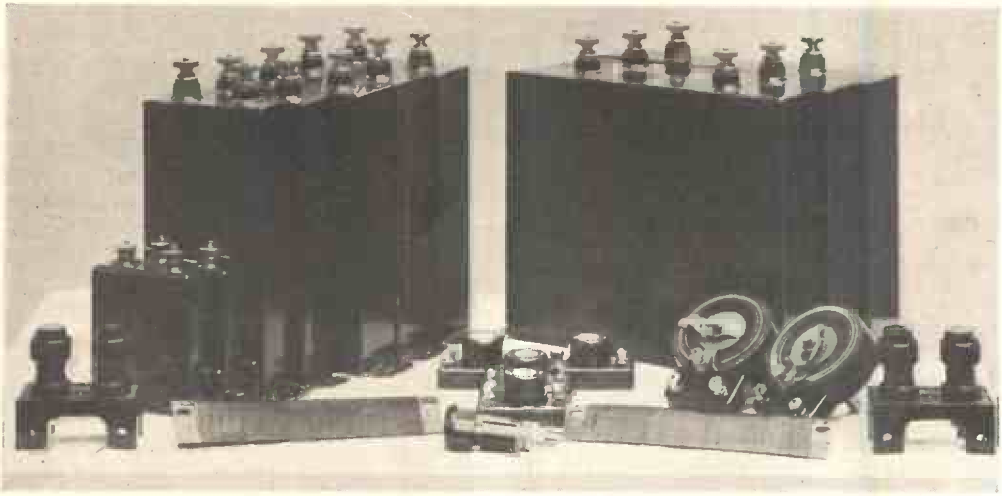


Fig. 6.—A Group of Smoothing Condensers, Resistances, Potentiometers and Terminal Blocks.

It is important that the condensers in this amplifier should be capable of standing a pressure of 800-volts working (not 800-volts test).

fitted with wood screws, as all these are light.

Layout

A convenient form of layout is that shown in Fig. 2. It has been carefully arranged so as to simplify the wiring as much as possible and prevent any interaction between the various components; but as most of the components are of the L.F. nature, a small rearrangement is not likely to affect the operation.

Hints about Wiring

All the wires used in the amplifier should be covered with high-voltage sleeving, particularly those carrying the anode voltages. Where there are terminals on a component, if the wire is properly twisted round the terminal and tightly screwed it will be just as effective as soldering; in fact, there is not the likelihood of a broken joint occurring as in the case of a soldered tag which has a poorly made joint. When the wires are twisted round the terminals it is advisable to place a washer on the top so that when screwing down the terminal nuts the loop is not distorted. Where the terminals are small, use a heavy gauge solder tag, passing a wire through the hole, bending it over and well soldering. Do not just solder the wire on to the tags, as this is not mechanically strong.

Wires from Filaments should be Twisted

The wires from the filament of the valve should be of heavy gauge and twisted together. The reason for twisting the filament wires is that they are carrying raw A.C. current, and if not twisted they set up hum in the amplifier due to interaction between the other leads. A large independent earth terminal is an advantage, as an amplifier should always be earthed.

ORDER OF ASSEMBLY AND CONSTRUCTION

Cover the baseboard with a piece of tin or copper, turning up the corners and driving into the board. Clean the paint from under the condensers, transformers, etc., so that they make good contact with the metal earth plate. Now proceed as follows:—

(1) Fix the mains transformer, smoothing choke, output filter choke, push-pull transformer, then the three 4-mfd. condensers and the one 2-mfd. condenser at the back of the board.

(2) Fix the three 2-mfd. condensers by the side of the mains transformer.

(3) Fix the two 1-mfd. condensers in front of the push-pull transformer.

(4) Arrange the small resistances and valve holders in a convenient position, making sure that there is sufficient clearance for the valves.

(5) Fit the three variable resistances on brackets, which can be made from pieces of brass bent at right angles. *It is important* to note that the potentiometer for the volume control and also the variable 15-ohm resistance (R. 6) must be insulated from the bracket, so make the holes in the bracket sufficiently large to allow for an insulating bush.

(6) The H.F. choke and the two small by-pass condensers are now fitted near to the first valve holder, where there is plenty of room.

(7) Lastly, the input and output terminal blocks are screwed into position, and as these are not fitted until after the wires are attached they can, therefore, be left until the last moment.

Why Control Knobs are Omitted

It will be noted that the control knobs for the filament resistance and the grid-bias resistance are omitted. This is done purposely, as without the knobs there is not the likelihood of anyone turning and altering the adjustment, for if this adjustment was altered, particularly in the case of the bias resistance, serious damage might be done to the valve. If one wishes, this variable resistance may be replaced by a fixed one; but the advantage of the variable resistance is that it may be adjusted to suit various types of valves.

The resistance R. 9 has been designed so that it may be fitted across the terminals of the smoothing condenser. This makes a convenient fixing.

The gauge of wire used in this resistance must be of ample size, as it is passing 120 m.a. approximately.

WIRING THE AMPLIFIER

Having now fitted all the components in position, we may proceed with the wiring. It is better to begin from the mains transformer end. First connect up the two small condensers across the primary, then wire up the rectifier valve and filament supply continuing on through the smoothing choke, resistances, output and push-pull transformer, as in the diagram, to the input terminal.

After having completely wired the amplifier, test out all the circuits so that you are certain that the correct values of resistances are used in the right position and that all condensers, where shown, are earthed. Here will be seen the advantage of using a metal baseboard, as the earth connections may be made direct to the metal casing of the condenser or from the terminal of the component and soldered to the metal covering. This adds to the neatness and saves long wiring, making a short return to earth where necessary.

What to do if Hum Occurs

If the amplifier has been carefully constructed with the components described, in operation it should be hum-free. If hum is encountered, first look to the brushes of the gramophone motor, should one be in use. Next, earth the frame of the gramophone motor and look to the leads of the pick-up. These leads should be screened and the carrier of the pick-up should be earthed. If there is still any sound of hum, it may be traced to a bad earth connection of one of the components.

Using the Amplifier in a Radio-Gramophone

If built into a radio-gramophone cabinet, the L.F. amplifier may be placed at the bottom and the detector and H.F. stages at the top, deriving the filament current and H.T. voltage from the common amplifier, for if the valves as specified are used, we have still approximately 10 to 12 milliamps. to draw upon.

In conclusion, the constructor will be amply repaid for constructing this amplifier, as without any doubt an amplifier of this description is an exceedingly useful instrument, being flexible with sufficient power to meet all the demands which will be required under ordinary conditions. It will be perfectly suitable for a small dance hall, tennis court, garden parties, etc.

SERVICING

THE LOTUS BAND-PASS 3 RECEIVER AND OTHER MODELS

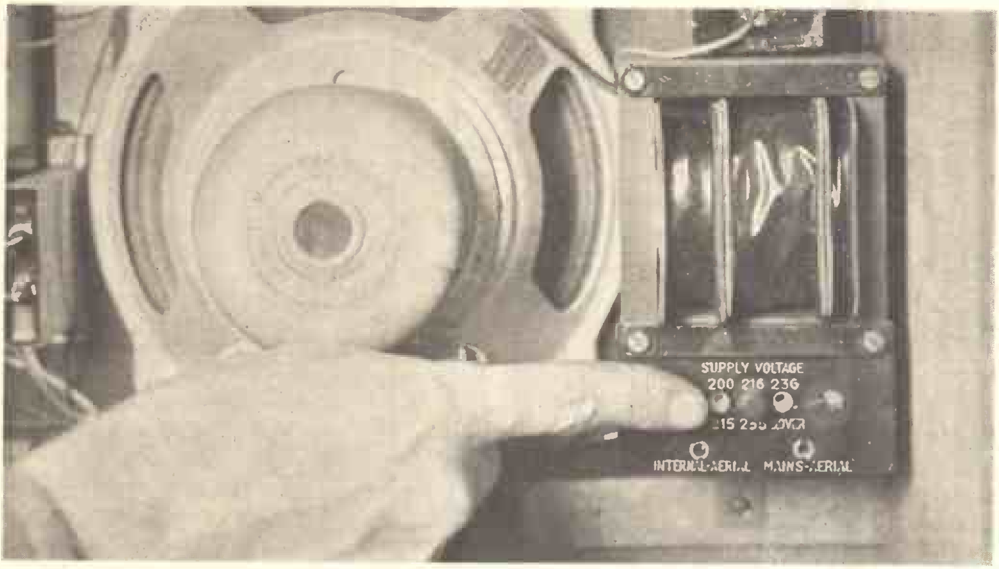


Fig. 1.—ADJUSTING THE SET TO THE CORRECT MAINS VOLTAGE.

This shows the A.C. Band-pass Receiver. The tapping screw should be screwed hard down into the appropriate socket.

ALTHOUGH the following instructions for servicing are more particularly intended to apply to the Lotus "Band-Pass 3," they can also be applied to the "Bud 2-Valve" and "Long Range 4" receivers, because all models have certain features in common, and the suggestions which follow may well be applied in dealing with the servicing of the two- and four-valve receivers.

They are all, for example, made in two units, one of which is the receiver proper, and the other the power pack and loud speaker. The necessary connections between the two are brought to a terminal plate, which permits rapid disconnection when necessary, and prevents any possibility of wrong connections being made when the set is assembled again.

An additional advantage provided by this method of construction is that all the circuits in the receiver have testing points accessible to the service engineer without there being any need to dismantle anything, and should a fault arise the set can be tested under working conditions and under its own power either in or out of the cabinet.

Preliminary Tests

It is usual in the Service Department at Lotus Works to make a preliminary test of any receiver returned for service by first checking over the voltage in the various circuits, as it is obvious that an intelligent consideration of the values obtained will often indicate the probable fault before any attempt is made to test individual components.

If the readings obtained are approximately correct, it is next tested on an oscillator which provides a signal of

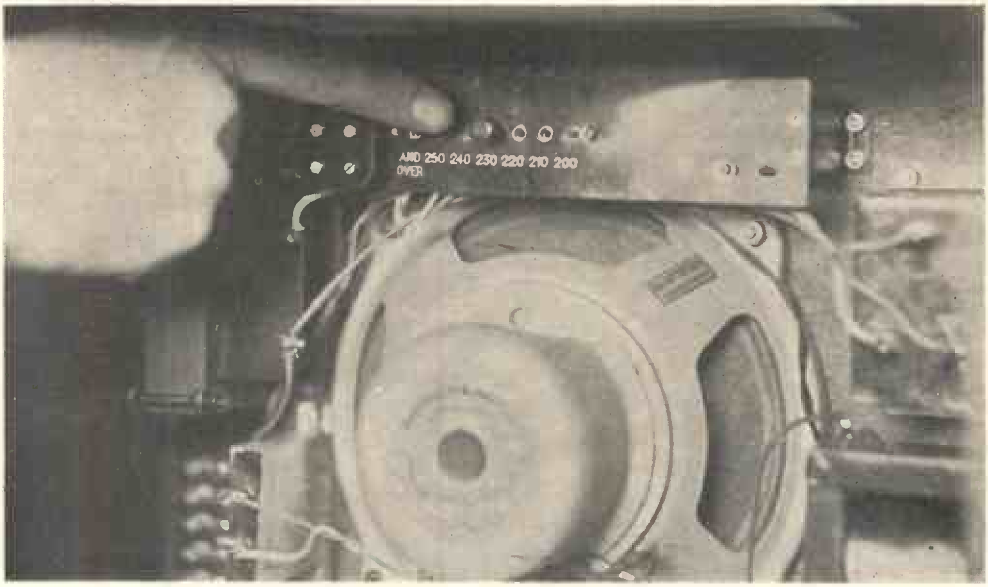


Fig. 2.—Adjusting the Set to the Correct Mains Voltage.
This shows the adjustment for the D.C. Band-pass Receiver.

known input, from which is expected a certain level of output measured on a standard load.

While it is not expected that every service engineer has the necessary facilities at his disposal for testing under these ideal conditions, the possessor of an oscillator will find his task as a service engineer greatly simplified by its use. Before passing to the actual method of servicing Lotus Band-Pass 3 receivers, a few remarks on the necessary equipment may be permitted.

Equipment Required

It is assumed that before attempting to service these receivers the engineer has provided himself with a high-resistance voltmeter reading up to 300 volts at least, and having a resistance of not less than 1,000 ohms per volt.

Fig. 3.—This shows the Position of the Mains Fuse which is fitted on the Terminal Strip behind the Set.

It is readily detached by removing the two terminal nuts.

The use of such an instrument in the ensuing tests is imperative, as the voltage values quoted hereafter are references to readings which are given by an instrument of this type.

If a low-resistance voltmeter is used, the readings taken will be uniformly lower than the actual value, and possibly a false impression of the condition of any component or circuit might be obtained by making a casual comparison of any voltage reading taken on test with the correct value given in these instructions.

Test the Valves

Before beginning the overhaul of any wireless receiver, it is advisable as a matter of routine to see that the valves fitted are all perfect, or to replace them in the initial tests with a set that is known to be perfect.

Careful attention to this point often saves many hours of labour, since certain defects in a valve may only become apparent after they have been working some time, and when the temperature has reached the critical point which produces a secondary emission from the grid, or a short circuit between two of the electrodes.

Fig. 4.—REMOVING THE TERMINAL STRIP.

All leads from the power pack and loud speaker to chassis are connected at this panel. Releasing the seven terminals permits the chassis to be removed complete, and obviates the necessity of unsoldering.

See that Condenser Vanes are Fully Engaged before Changing Valves

A further precaution that should always be taken is to engage fully the vanes of the ganged tuning condensers before proceeding to change valves, or, indeed, to perform any operation of testing or adjusting.

This is to save any accidental bending of the slotted end vanes, whereby the tuning over part of the range might be thrown out of gang and the efficiency of the receiver considerably reduced.

Adjusting Set to Correct Mains Voltage

Before switching on the mains current the set should be adjusted to suit the correct mains voltage by screwing the tapping screw hard down into the appropriate socket.

The position of this screw is clearly shown in Figs. 1 and 2, which illustrate the A.C. and D.C. models respectively. A perfect connection must be made at this point, as a bad connection produces harsh grinding noises from the speaker.

Mains and Wavechange Switch

The mains current switch is operated by turning the wavechange from the "OFF" position either to the left or right until the white dot on the knob registers over the words "LONG" or "SHORT," with a distinct click from the automatic lock, which is provided for each working position.

After switching on, the pilot lamp should light immediately and the valves attain a working temperature in from thirty to ninety seconds. If the set remains dead after switching on, the current supply to the receiver should be checked, the plug and leads examined, and the fuse on the receiver inspected.

Mains Fuse

The mains fuse is fitted on the terminal strip behind the set, and its position is indicated in Fig. 3. It is of the gold film type, and is readily detached by removing the two terminal nuts, as shown in the illustration. It should be replaced if it shows any sign of cracking in the gold film, or if the film is definitely broken.

Correct Size of Fuse

If it blows at once when the receiver is switched on again, the cause must be found before fitting another fuse, and no attempt should be made to strengthen the fuse and to try again.

Serious damage may be done to other

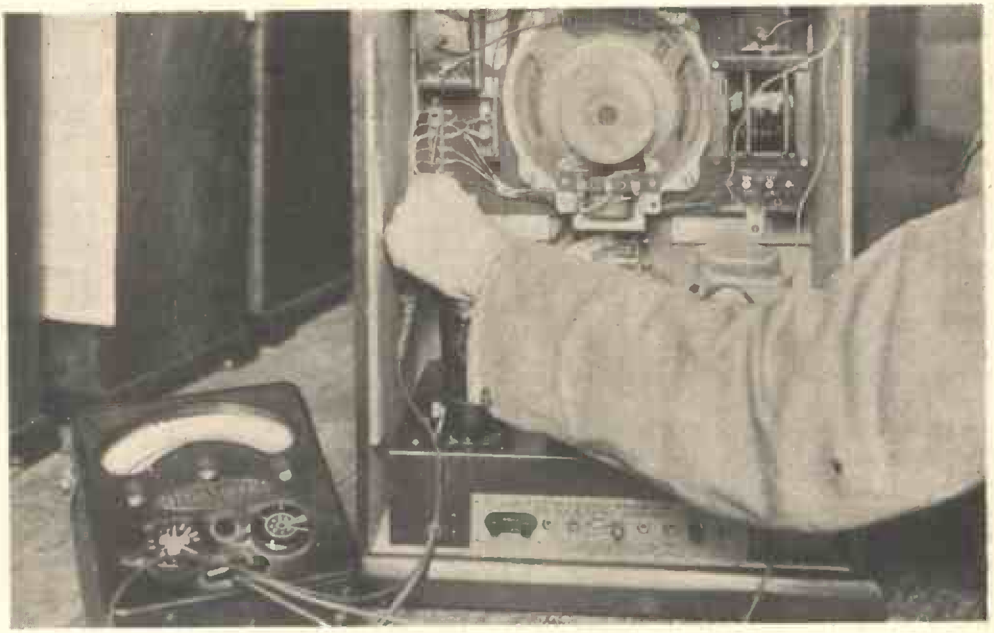


Fig. 5.—Testing Voltages at the Terminal Strip.

An insulated test prod is used as the moving positive pole and the negative or earth lead is made by clipping a wire to the case of the electrolytic smoothing condenser (see Fig. 6). This photograph shows the test prod on one of the L.T. connections from which is taken the current supply to the valve heaters. High tension, low tension (A.C.) and mains can be checked in this manner.

delicate components if the set is put on load with a heavier fuse than that fitted. The correct size of fuse fitted to the A.C. set is 400 m.a., and in the D.C. model 800 m.a.

Checking over D.C. Voltages at Various Points

If the valves heat up and the pilot lamp lights, it will be opportune at this stage to check over the D.C. voltages at various points in the receiver. The method to be adopted is as follows :—

Voltage Tests from Terminal Strip

On the left of the speaker will be found a terminal strip carrying seven contacts (see Fig. 4).

All the leads from the power pack and loud speaker to the chassis are brought to this panel and are arranged in the following order, beginning at the top contact.

For A.C. Receivers

No. 1.—H.T.–
,, 2.—H.T.+ Should read 200/230 volts A.C.
,, 3.—Pentode plate (speaker lead) should read 190/215 volts.
,, 4.—L.T. } Should read 4 volts A.C.
,, 5.—L.T. }
,, 6. } Mains. Should read mains voltage.
,, 7. }

For D.C. Receivers

No. 1.—H.T.+
,, 2.—Pentode plate. Should read about 200 volts.
,, 3.—L.T.+ } Approx. 100 volts, subject to a variation of 15 per cent.
,, 4.—L.T.– }
,, 5.—Mains – } Should read mains voltage.
,, 6.—Mains + }

The method of taking these voltage readings is shown in Figs. 5 and 6.

Terminal Voltages

In addition to the above tests, further

Fig. 6.—Testing Voltages at the Terminal Strip.

Here we see the test prod on the high-tension negative contact. Note the clip earthed on the electrolytic condenser to complete the circuit.

readings should be taken at the following terminal points :—

	Volts.
S.G. valve anode .	180
S.G. valve screen .	70–80
Detector anode . .	90–100
Pentode auxiliary grid	200
Positive side of rectifier chassis . . .	300–350
Across L.S. field (two outer contacts on L.S.)	100–130

These figures will be somewhat higher on the Long Range Four.

These readings are taken by touching the appropriate terminal or valve-pin on the valve with the test prod, as in Fig. 7, showing the checking of voltage at auxiliary grid of pentode valve.

If the test readings obtained are substantially in agreement with the values just specified, it may be taken for granted that the mains transformer, rectifier, load condensers and resistances are in order.

Procedure when Valves do not Heat Up after Switching On

If, after the mains plug and cords have been examined, and, if necessary, the fuse has been replaced, the valves do not heat up after switching on, a voltage test should be made across the two bottom contacts on the seven-point terminal strip. The voltmeter used should read 250 volts A.C. or D.C., according to the type of receiver under test, and the reading obtained should be that of the mains supply. No reading suggests a broken mains lead, or connection between the switch and terminal strip, or that the mains switch

Fig. 7.—Checking Voltages at the Auxiliary Grid Terminal of the Pentode Output Valve.

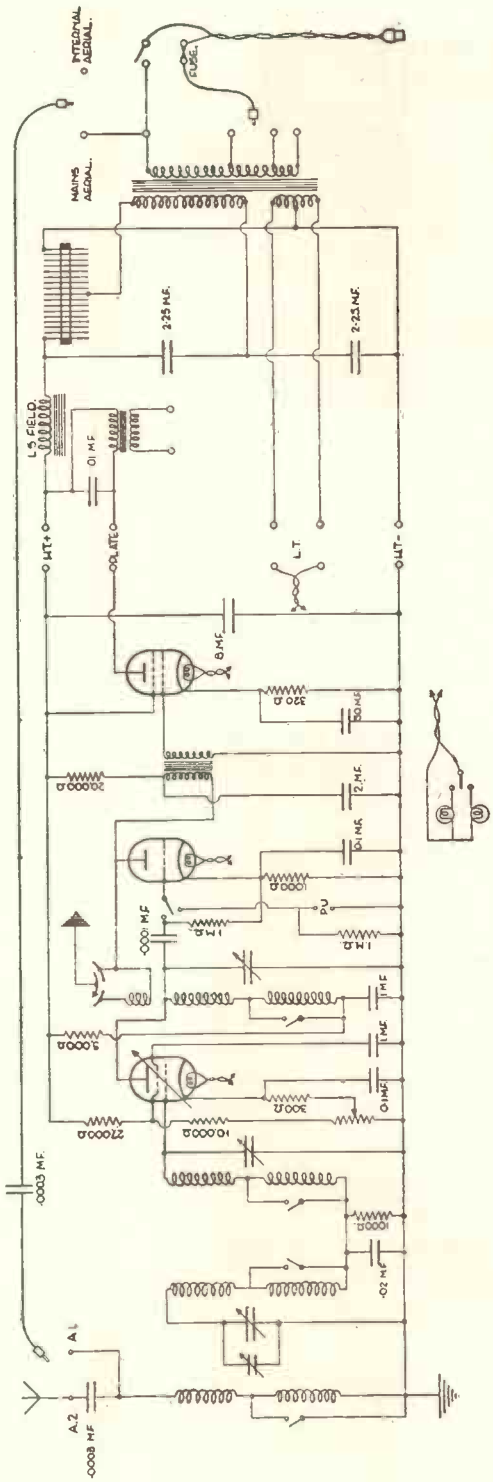


Fig. 7A.—THEORETICAL CIRCUIT DIAGRAM OF THE LOTUS A.C. BAND-PASS THREE RECEIVER.

is faulty or is not being operated by the cam.

This diagnosis can only be proved by withdrawing the chassis from the cabinet. The cam should push the switch arm hard over in the "ON" position, and on the reverse movement allow it to spring back, so that the switch knob is distinctly loose between the sides of the channel of the cam.

To Withdraw Chassis and Power Pack from the Cabinet

The correct way of doing this is clearly shown and explained in Figs. 9, 10, 11 and 12.

Replacing the Units

After removal from the cabinet, the units may be connected together again by replacing the seven contact-screws in the terminal strip. The set can then be tested under its own power with the chassis inverted so that the connections and components under the chassis are in full view and readily accessible for test or replacement.

Checking the Detector and Amplifying Stages

When the valves do heat up and everything appears to be in good order, the detector and amplifying stages may be roughly checked before testing on radio or gramophone, by turning the wavechange switch to "GRAM" and touching the detector grid side of the pick-up sockets with a moistened finger.

If these circuits are in good condition the fact will be indicated by loud screeches or rumbling noises from the speaker. This test is generally known to the experienced engineer, who will be able to gain a considerable amount of information from the volume and quality of the noise produced.

The method of applying this test is shown in Fig. 13.

Weak Response

A weak response from the speaker

when this test is applied indicates broken circuits, faulty intervalve transformer, low emission from valves or drop in current supply to the valves, due to faulty feed resistances or smoothing condensers. When a weak response is given to this test it is advisable to concentrate on clearing the fault before proceeding to attend to the tuned portions of the receiver.

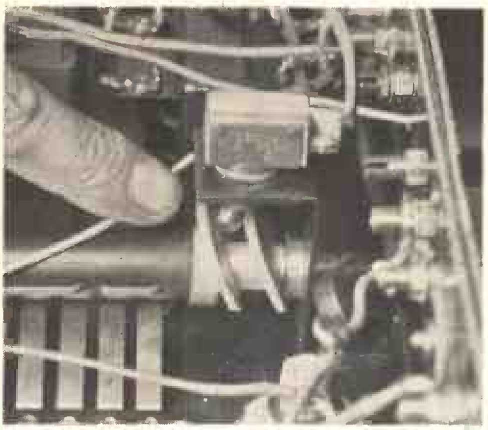


Fig. 8.—Examining the Cam-Operated "On-off" Mains Switch.

Make sure that the cam pushes the switch arm hard over in the "on" position.

Good Response

A good response from the speaker suggests that the detector and amplifying stages are in order, and this should be proved by a further test on a gramophone pick-up.

To assist identification of the various components under the chassis, a schematic diagram of the A.C. receiver circuits is shown, with resistance and capacity values marked against the respective parts.

In Fig. 15, depicting a D.C. receiver, the addition of a 1-mfd. condenser is shown. It is situated in the corner of the chassis, where it is shown under insulation test. Its function is to insulate the receiver "earth" from the mains while passing radio-frequency signals.

Fig. 9.—How to withdraw the Chassis and Power Pack from the Cabinet.

The first operation is to remove the control knobs which are attached to the spindles by grub screws.

Layout of Wave-change Switch

The illustrations of the undersides of the various chassis show very clearly the layout of the wavechange switch and the disposition of its several component parts.

The leads are brought to thirteen contact blades, which are mounted in banks of 5, 3, 2, 3. Connecting pieces are mounted on an ebonite rod, which can be rotated and brought into contact with the blades, thus effecting the necessary variations of contact in changing wavelength over which the set will tune and in adapting it for use with a gramophone pick-up.

The mains switch is operated by a cam mounted at the end of the ebonite rod.

How to Distinguish the Different Switch Blades and Contacts

In order to distinguish the

different switch blades and contacts, we will begin with the blade nearest the mains switch cam. It is the first blade in the bank of 5. Calling this No. 1 and numbering to the left 1 to 13, the connections are made as follows ;—

No. 1.—To centre tap of band-pass aperiodic coil.
,, 2.—To end of L.W. portion of band-pass aperiodic coil and earth.

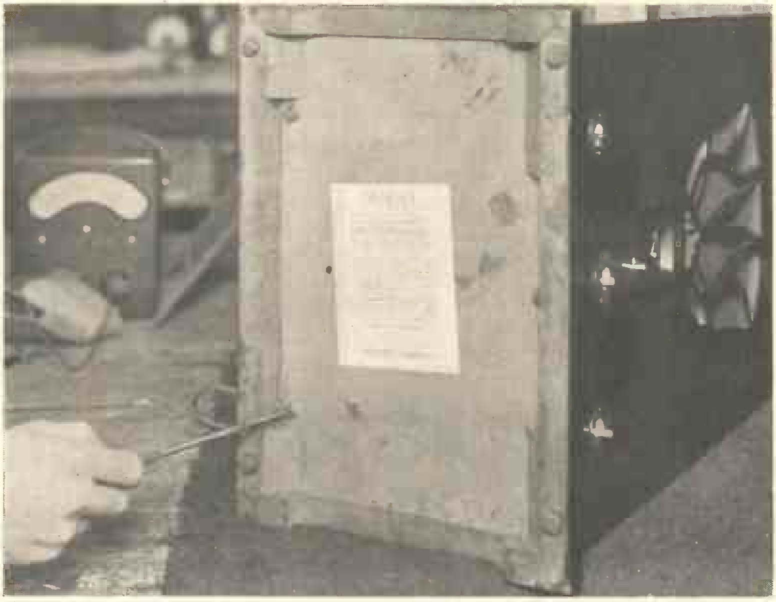


Fig. 10.—How to withdraw the Chassis and Power Pack from the Cabinet.

Removing the three retaining screws, the heads of which will be found under the base of the cabinet. It is advisable to cover the working bench with a piece of blanket or felt while the cabinet is being laid on its side to prevent scratching the polish.

No. 3.—To centre tap of tuned portion of band-pass unit.
,, 4.—To centre tap of H.F. valve grid coil.
,, 5.—To end of L.W. loading coil in band-pass unit and of H.F. coil, and to ·02-mfd. coupling condenser and resistance.
,, 6, 7, 8 are leads to pilot lamp change-over switch.
,, 9.—To centre tap of H.F. valve anode coil.
,, 10.—To end of L.W. section of H.F. anode coil.
No. 11.—To detector grid side of ·0001-mfd. condenser.
,, 12.—To detector grid.
,, 13.—To pick-up socket.

In the D.C. mains model blades Nos. 6, 7, 8 are not fitted, as only one pilot lamp is used, and is connected directly across the mains. A study of the schematic diagram will show that there are four short-circuiting switches fitted in the tuning circuits.

If we call the switch on the band-pass aperiodic coil No. 1 and number 1–4 to the right, it will be seen that switch blades 1 and 2 are contacts of shorting switch No. 1. Blades 3, 4 and 5 are switches 2 and 3, blade 5 being common contact to the band-pass coupling condenser and resistance. Blades 9 and 10 are switch No. 4, and 11, 12, 13 and the radiogram change-over switch.

Cleaning the Wavechange Switch

In Fig. 14 will be seen a suggested method of cleaning the contacts of the wavechange switch should this operation ever become necessary. A piece of clean notepaper, or fine emery cloth, is passed between the contacts and held there while the switch is rotated. If it is gently pulled out while the shorting strips are in registration any foreign matter will be removed without danger of bending the switch blades.

Feed and Decoupling Resistances

The mains current feed resistances in

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SHORT WAVE RECEPTION

Making a **DOUBLE PUSH-PULL RECEIVER**

UNITS AND MEASUREMENTS

SERVICING KOLSTER-BRANDES RECEIVERS

1/-

Part 26

IN 32 WEEKLY PARTS

PART 26.

the three valve A.C. Receiver are mounted on a bakelised linen strip under the chassis, and, viewed from left to right, valve sockets being on the left, they are arranged as follows :—

No. 1.—300-ohm fixed resistance in series with sliding arm of potentiometer regulating grid bias of S.G. valve.
,, 2.—1,000 ohms is detector valve G.B. resistance, coming into operation when set is switched over to " GRAM."
,, 3.—10,000-ohm H.F. valve screen decoupling resistance.
,, 4.—27,000-ohm H.F. valve screen voltage regulator. Nos. 3 and 4 are in series with each other and with the G.B. regulating potentiometer (volume control).
,, 5.—5,000-ohm H.F. valve anode resistance.
,, 6.—20,000-ohm detector anode resistance.

Fig. 11.—How to withdraw the Chassis and Power Pack from the Cabinet.

The seven-way contact strips should be detached by taking out the connecting screws. The chassis will slide out of the cabinet as shown.

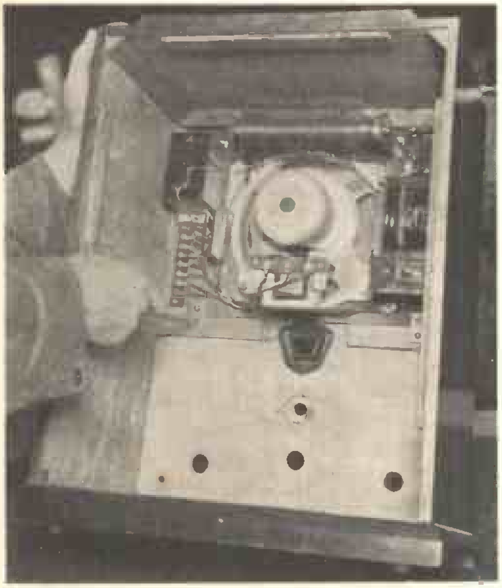


Fig. 12.—How to withdraw the Chassis and Power Pack from the Cabinet.

The speaker and power pack are mounted as one unit on the baffle board, which is attached to the frame of the cabinet by four brackets. Removal of four screws enables the unit to be lifted out complete.

This completes the description of the disposition and conditions of working of the main components used in this receiver, and from it will be seen how easy it is, by following the routine of the circuit tests described, to gather a precise knowledge of the condition of any Lotus " Band-Pass 3 " receiver without dismantling anything or withdrawing any part from the cabinet.

CLASSIFICATION OF FAULTS IN RADIO RECEIVERS

Possible faults with their diagnosis and cure will be dealt with under five headings as follows :—

(*a*) No response after switching on. Valves do not heat up.

(*b*) Valves heat up, but no response from speaker on either radio or gramophone.

(*c*) Weak reproduction of both radio and gramophone.

Fig. 13.—CHECKING UP THE DETECTOR AND AMPLIFYING STAGES OF THE RECEIVER.

This is done by placing a wetted finger on the detector grid side of the pick-up sockets with the wave-change switch at " Gram." If these circuits are in good condition the fact will be indicated by loud screeches or rumbling noises from the speaker.

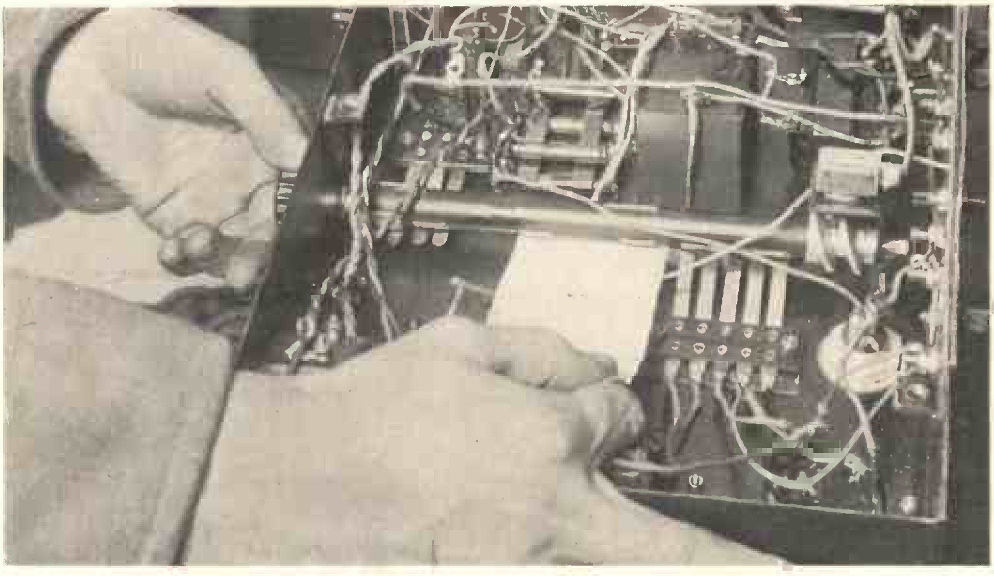


Fig. 14.—HOW TO CLEAN THE CONTACTS OF THE WAVE-CHANGE SWITCH.

This is done by inserting a piece of clean notepaper or fine emery cloth, which is held in position while the switch is rotated. This illustration shows the A.C. model, but the method is similar with the D.C. and battery models.

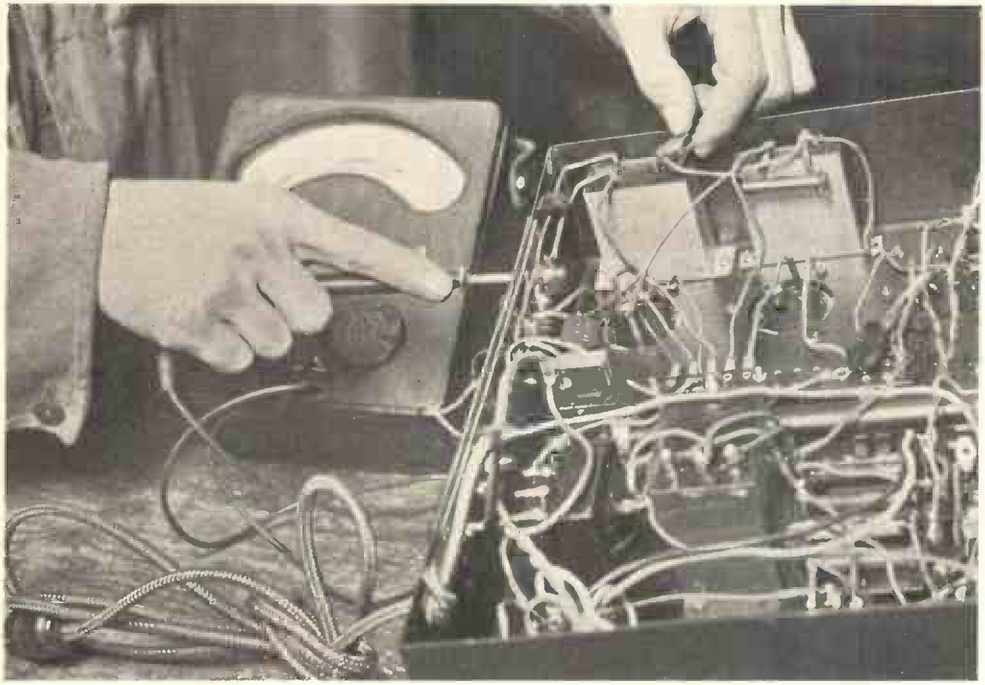


Fig. 15.—A View of the Underside of the D.C. Receiver.

In this receiver there is an additional 1-mfd. condenser, and here we see an insulation test being applied to this condenser. The function of the condenser is to insulate the receiver "earth" from the mains while passing radio-frequency signals.

(*d*) Weak or distorted radio, good gramophone.

(*e*) Good radio, weak or distorted gramophone.

A. NO RESPONSE AFTER SWITCHING ON. VALVES DO NOT HEAT UP

Directions for dealing with (*a*) have already been given, and are briefly summarised as follows :—

(1) Examine mains lead and plug for broken joints or break in lead.

(2) Inspect fuse on set, and see that tapping screw is screwed down hard.

(3) Test voltage across contacts 6 and 7 on terminal strip. Should read mains voltage. If no reading—

(4) Withdraw chassis and check action of mains switch, and inspect for broken joints.

B. VALVES HEAT UP, BUT NO SOUNDS FROM SPEAKER

(1) Be sure that contact to pentode auxiliary grid is not broken.

Checking Output Valve

(2) Check output valve in another set or replace with one known to be perfect.

Immediately current is switched on with a new valve, test grid bias voltage between pentode cathode and chassis. This should read 10·5 volts. This precaution must always be taken when a new pentode is fitted, as, if the previous valve has failed through internal short circuit, the G.B. resistance will almost certainly be burnt out and serious damage might be done to the new valve in a few minutes if it is allowed to run with incorrect grid bias.

Testing Loud Speaker

(3) Test speaker with phones plugged into sockets for extension speaker. If

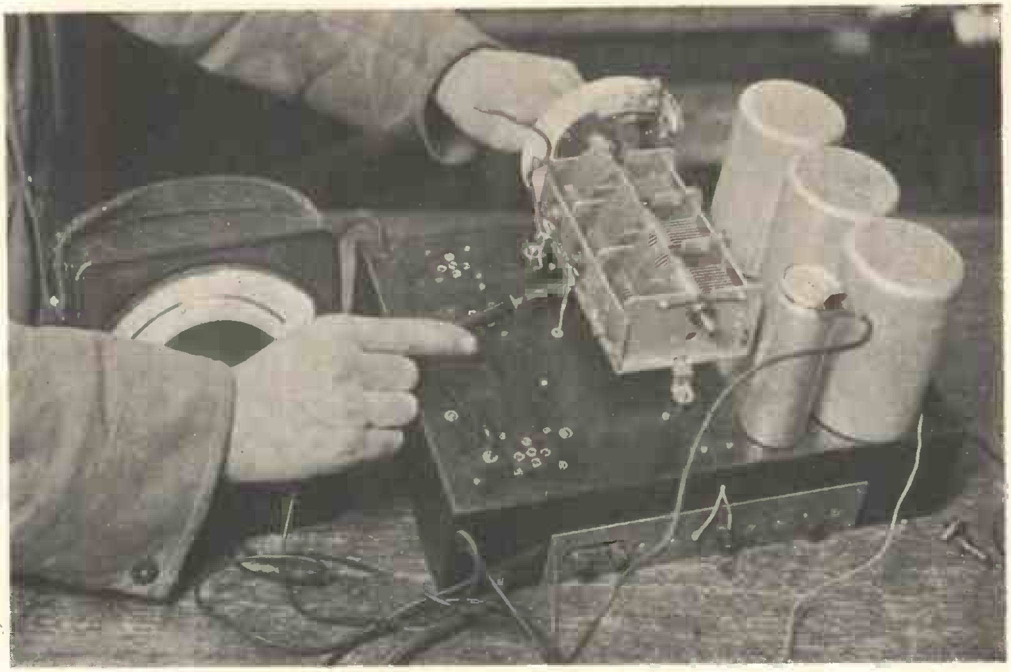


Fig. 16.—Testing for Shorting in Sections of the Gang Condenser.

This test is made with either a galvanometer or a voltmeter. A battery is placed in series with the voltmeter leads and the test prod makes contact with the fixed vane terminals while the vanes are slowly rotated. There are no trimming operations, as the trimmers are sealed and should only be corrected at the factory or service depot.

signals are heard in phones, either the speech transformer or speech coil are disconnected, and the speaker must be changed.

If no Signals are Heard in Test (3)

(4) Test volts between positive side of rectifier and chassis (300–350 volts).

(*a*) *If no Reading.*—Inspect leads from mains transformer secondary to centre contacts of rectifier and load condensers and outer contacts of rectifier to load condensers. If these are perfect, disconnect lead from centre contact of rectifier, and test volts between this wire and centre of load condensers. An A.C. meter should be used, as the test is direct off transformer secondary. Voltage should be 200–210 volts.

If the mains are up to standard voltage, a lower reading than the 200 volts will indicate failure of mains transformer secondary, and rewinding will be necessary.

(*b*) *Low Reading.*—If reading obtained under test (4) is seriously below 300 volts, detach lead from centre of load condensers and test transformer secondary as above (200 volts). If correct, the fault is proved to be in one of the 2·25-mfd. condensers. The whole block should be changed.

Testing Volts in Pentode Auxiliary Grid

(5) If 300 volts is registered under test (4), test volts on pentode auxiliary grid (between side terminal on cap and chassis), and on terminal 4 on seven-way strip. Both should read 200/230 volts.

Results above 200/230 volts indicate that speaker field is partly short-circuited; below 200 volts that the field coil has a high-resistance joint in its circuit. The volts across the two outer contacts on the speaker should be 100–130. Smaller value proves partial short circuit.

(6) Test voltage on No. 5 contact on seven-way strip (190 volts). No reading shows broken joint or lead from speech transformer, or disconnected primary winding in same. High reading suggests partial short circuit in speech transformer primary.

C. WEAK RADIO AND GRAMOPHONE RECORD REPRODUCTION

Inability to produce signals at normal loud speaker volume may be due to any of the following causes:—

(1) Use of One or More Faulty Valves

The valves should be checked for emission or the set tested with valves of known efficiency.

(2) Bad Contact of Valve Pins in Valveholder Sockets

This fault may produce intermittent crackling noises in the speaker, as well as continued poor volume. The valves should be moved about in their sockets while the set is working, and, if the trouble is discovered to be due to this movement, a cure can be made by slightly bending the pins of the offending valve, so that they make hard contacts in the sockets.

(3) Fault in Speaker

This might be a breakdown of speech or field coils, dust in air gap, warping of speech coil former, causing the speech coil to rub on the polepieces, and thus to damp free movement of the diaphragm or cause actual damage to the cone.

If lack of volume is accompanied by poor quality, the trouble is very probably in the speaker itself, and the quickest way to check this is to substitute

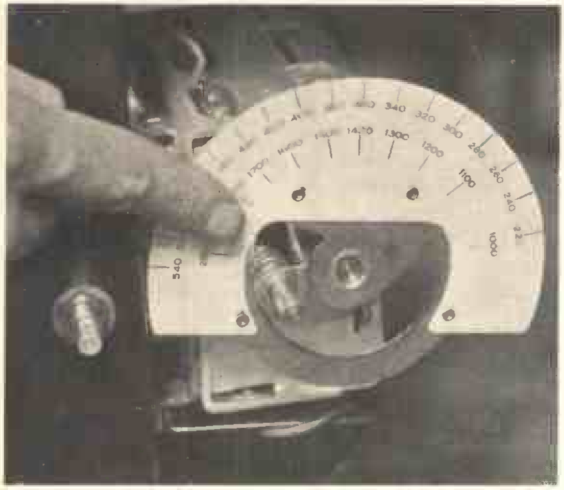


Fig. 17.—This shows where the Driven Disc has been Cut Away at the End of the Drive to allow it Slipping Over the Drivers and Bracket.

When reassembling, care should be taken to see that when the vanes are entirely disengaged and up against the stop the drivers are still gripping the disc as shown.

Fig. 18.—This shows a Fault that might be found in a Set which has been removed from the Cabinet.

The pigtail of the reaction condenser has been accidentally pulled out so that it can touch the terminal of the fixed plates. Such contact short circuits the reaction condenser.

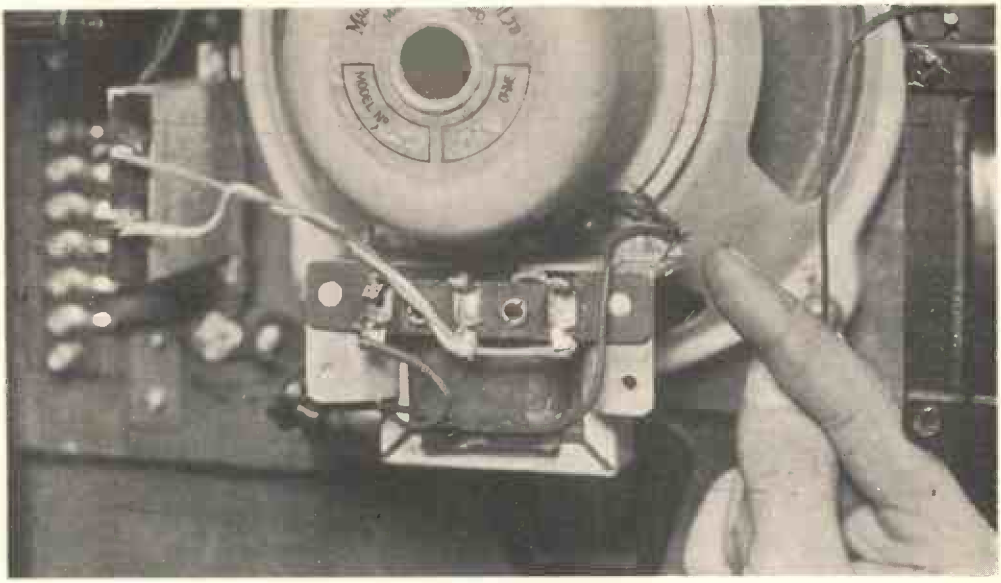


Fig. 19.—A Likely Point for Broken or Loose Connections.
This shows the D.C. set where the chassis of the speaker is connected to earth.

another speaker, or to plug another into the sockets provided. A faulty field coil is dealt with in tests under group B.

(4) Insufficient Current Supply to Valves

This may be due to breakdown of feed resistances or smoothing condensers, or to failure of the mains transformer. Investigation and treatment for these troubles have been dealt with under group B, sections (4), (5) and (6).

(5) Dirty Contacts on Wavechange Switch

These should be cleaned, as shown in Fig. 14.

(6) Short or Open Circuit in Intervalve Transformer Primary or Secondary Windings

Short circuits in either windings will produce distortion of output as well as lack of volume. Continuity of resistance tests should be made on each winding.

The normal resistance of the primary is 800 ohms, and of the secondary 3,000 ohms.

A break in the primary coil will be shown by testing the detector anode volts. If there is a break there will be no reading, but in the case of no reading being obtained the 20,000-ohm anode resistance should be tested also, as a failure here would produce the same result.

A short circuit in the secondary coil is difficult to prove, since it may be a few turns only, which might have little effect on the resistance of the whole coil and yet be enough to produce weak and distorted music.

If the L.F. transformer is suspected at all it is better to change it at once and test again.

(7) Bad Contact

Test between L.F. transformer primary and 2-mfd. bypass condenser, or between this condenser and chassis.

(8) Failure of Insulation in 2-mfd. By-pass Condenser

Failure at this point is dealt with later in this article, and would be indicated by a drop in detector anode volts. In addition, there would be pronounced heating of the 20,000-ohm resistance.

It should be noted in passing that a high-resistance joint in the detector anode circuit—H.T. positive to 20,000 ohms resistance to L.F. transformer primary—

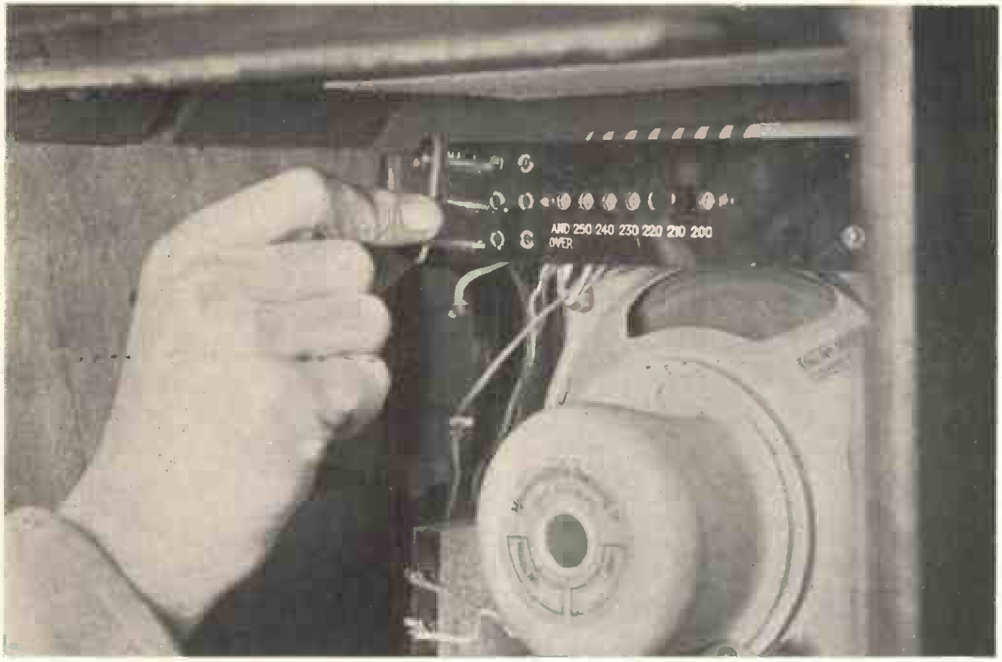


Fig. 20.—A Possible Cure for Mains Hum in the D.C. Receiver.

Owing to the fact that D.C. sets are required to work on mains where either the mains positive or negative may be " earth," a provision has been made whereby a choke can be connected in either pole of the heater current supply. This takes the form of a six-pin plug, as shown. This plug should be reversed when mains hum is noticeable.

might also produce a low voltage reading from the detector anode.

(9) Incorrect Pentode Grid Bias

Should be 10·5 volts. A high reading at this point would indicate a bad connection in the pentode cathode circuit, and would suggest an inspection of the G.B. resistance connection and a verification of its value, which is 320 ohms.

Low G.B. reading points to failure of the 50-mfd. G.B. bypass condenser, which is of the electrolytic type. It is not likely that the G.B. resistance itself will become reduced in value.

D. WEAK OR DISTORTED RADIO, GOOD GRAMOPHONE

The fact that reproduction of gramophone records is good proves that the detector and output stages are in order, and that the current supply to these valves is normal. The fault must therefore lie in the pre-detector portion of the receiver, and in consequence the field of search for the trouble is very much limited.

In this group of possible faults may be considered those which produce irregular interference with good quality reception, as well as uniform distortion or weak volume. They may be :—

(1) Faulty S.G. valve.

(2) Valve pins making bad contact in sockets.

(3) Derangement of components controlling current supply to S.G. valve.

(4) Damage to tuning condensers.

(5) Broken or dirty contacts in wave-change switch.

(6) Damaged tuning coils.

(7) Breakdown of insulation in reaction condenser.

(8) Damage to detector grid condenser (·001 mfd.) or grid leak.

Notes on Faults (1), (2) and (3)

Of these causes, Nos. (1), (2), (4) have been previously dealt with. With regard to No. (1), however, the engineer would be well advised to run the S.G. valve for half an hour before testing its emission, or commence his tests with a valve which is known to be perfect.

The reason is that this type of valve will often work perfectly for some minutes until it reaches a certain temperature, when, owing to displacement of the electrodes, the efficiency suddenly falls and reception ceases. In certain cases the readings of voltages from valve anode and screen will give no indication of the failure, and much time can be wasted in a fruitless search for the trouble elsewhere.

If the new valve does not immediately restore the efficiency of the set, test No. (3) should be proceeded with, and the voltage at screen and anode taken. They should be 70–80 on the screen and 180 on the anode.

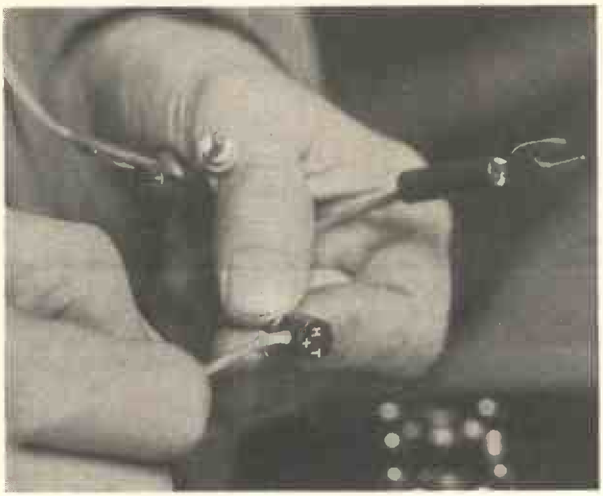


Fig. 21.—A Very General Fault in Battery Receivers.

It is often found that repeated insertions and withdrawals of the H.T. battery plugs result in a fracture of the battery lead close to the plug. Such faults are generally indicated by weak signals, often accompanied by continuous crackling from the loud speaker.

Checking Resistance Values

Regulation of voltage at these points is controlled by resistances Nos. 3, 4 and 5, values 10,000, 27,000 and 5,000 ohms respectively. If the voltages recorded are not as specified, the resistance values should be checked and all joints examined for failure. No voltage readings at either screen or anode accompanied by heating of either the 27,000 or 5,000-ohm resistance denotes a breakdown in the insulation of one of the 1-mfd. decoupling condensers. The connections to these condensers should be broken, so that they may be individually tested.

The Potentiometer Controlling Grid Bias

If screen and anode voltages are correct, the potentiometer controlling grid bias should receive attention.

The grid bias voltage should first be checked by testing between cathode pin and chassis, and it should be possible to vary it between 1·5 and 40 volts by turning the potentiometer (volume control).

Dirty Slider Contacts

It may happen that after a set has been in use for a considerable time the slider contacts have become dirty, and that when the slider is rotated the voltage recorded is inclined to flicker. If this occurs the potentiometer should be replaced, as it may be the cause of both weak and noisy reception.

It should be noted that in the battery model a variable-mu valve is not fitted. The potentiometer in this case is connected across the aperiodic coil of the band-pass unit, and the remarks on variation of grid bias do not apply.

(4) Damage to Tuning Condensers

Damage is frequently done to the ganged tuning condensers through attempting to insert a new pilot lamp or valve, or to make some small adjustment without first fully engaging the vanes so that the split end vanes are protected.

When such bending is enough to cause the vanes to touch the trouble is not difficult to diagnose, as reception will cease entirely when the vanes are in contact.

A slight distortion of one of the vanes may be marked by a distinct loss of volume from stations which tune in on that part

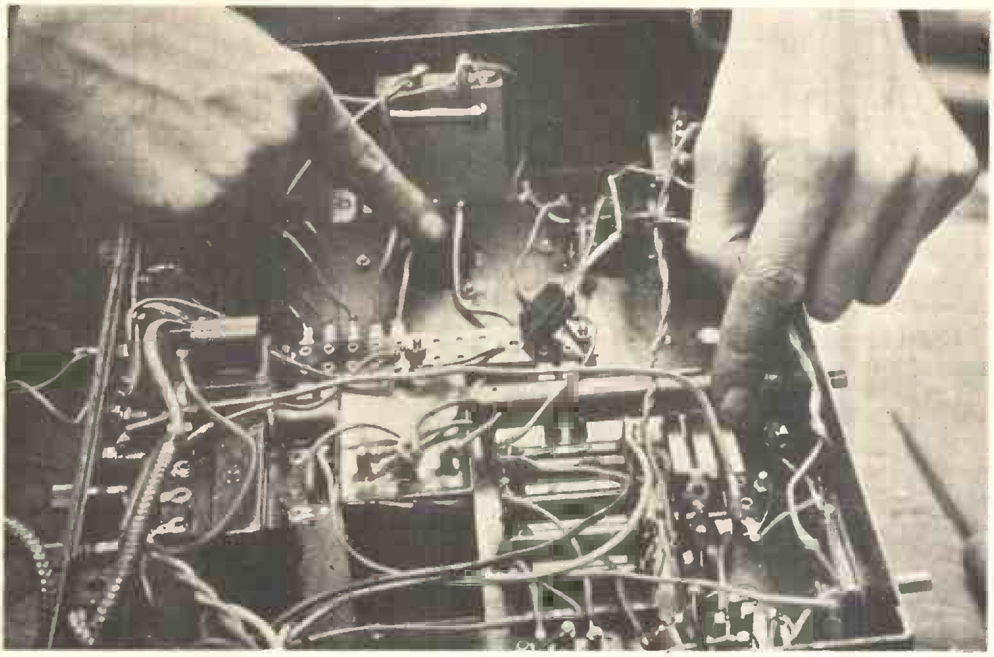


Fig. 22.—A Fault which might happen in any Set.

This is a short circuit caused by the earthed metal sleeve which shields the pick-up H.F. grid and anode leads becoming bent so as to touch some other part of the circuit. Under normal circumstances its stands quite clear of all contacts, but it may be accidentally bent in handling the chassis when removed from the cabinet, or get pushed along on its own lead until it touches the soldering tag and short circuits the wire it is intended to shield.

of the dial where the plates have been thrown out of gang.

Breakdown of Insulation

Breakdown of insulation in the tuning condensers is very unlikely, but if it is suspected it may always be tested either with a galvanometer or voltmeter in the manner illustrated in the photograph, where a battery is placed in series with the voltmeter leads and the test prod makes contact with the fixed vane terminals while the vanes are slowly rotated.

It should never be necessary to alter the trimmers unless one of the units has suffered accidental damage. They are sealed at the works after the circuits have been ganged on an oscillator, which is much more accurate than any system of aural checking.

Detaching the Disc Drive

If it should ever be found necessary to detach the disc drive and scale from the condenser shaft, provision has been made whereby the disc can be slipped out of the driving wheels after the grub screws attaching it to the shaft have been slacked off.

Fig. 17 shows where the disc has been cut away at the end of the drive to allow it slipping over the drivers and bracket.

When reassembling, care should be taken to see that when the vanes are entirely disengaged and up against the stop the drivers are still gripping the disc as illustrated.

(5) Broken or Dirty Contacts in the Wave-change Switch

Instructions for dealing with this trouble have already been described (see Fig. 14).

(6) Damaged Tuning Coils

Suspected damage to the tuning coils should always be checked first by removing the shields.

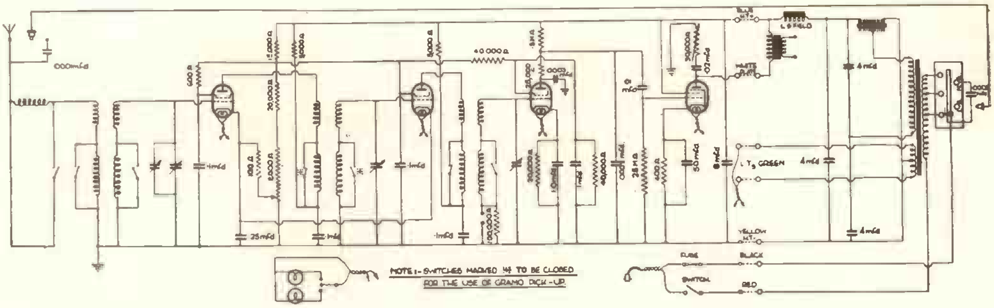


Fig. 23.—Theoretical Circuit Diagram of Lotus "Long Range 4" Receiver.

Continuity and resistance tests may be made by following the plan of connections given in the section dealing with the wave-change switch.

The resistance of the short-wave sections is 3 ohms per coil. The combined long and short-wave sections have a resistance of about 13·5 ohms per coil.

A damaged coil must be returned to the works for rewinding, so that the inductance is correctly matched.

(7) and (8) Breakdown of Insulation of Reaction or Grid Condensers

These faults are of unlikely occurrence, but for reference the symptoms are described.

Short-circuiting of the reaction condenser would be indicated by the heating up of the 20,000-ohm anode resistance and probable burning out of the L.F. transformer primary.

In the battery set the heating would be found in the 30,000-ohm resistance, and the H.T. battery would rapidly run down.

Fig. 18 is intended to describe a fault which might be found in a set which has been removed from the cabinet, and in handling has had the pigtail on the reaction condenser pulled out so that it can touch the terminal of the fixed plates. Such contact short circuits the reaction condenser and would give rise to the above symptoms.

The chassis illustrated is the battery model.

E. GOOD RADIO, DISTORTED GRAMOPHONE

The pick-up and volume control used with the receiver should be tested first, either by substitution or by testing them with another receiver.

A fault in the set can only be situated in either the grid bias resistance (1,000 ohms) or by-pass condenser (0·1 mfd.), or in the switch contacts Nos. 11, 12, 13, and leads from the pick-up sockets to these contacts, and should therefore be readily detected.

An increase in reproduction of notes in the higher register, which is indicated by increase of record scratch and generally shrill music, indicates a bad connection in the shunt resistance across the pick-up. The resistance itself is unlikely to cause trouble, and it should be noted that its value is 20,000 ohms, and not 1 megohm, as marked on the schematic diagram.

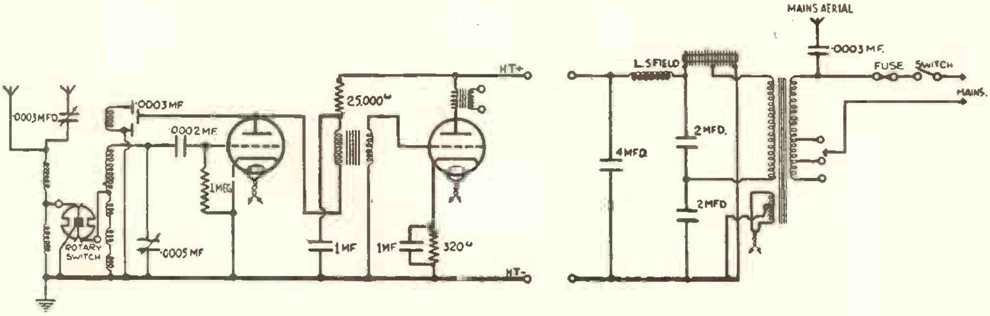


Fig. 24.—Theoretical Circuit Diagram of Lotus "Bud 2 Valve" Receiver.

SHORT-WAVE RECEPTION

By FRANK PRESTON

THERE is no doubt that the popularity of short-wave reception is rapidly increasing, due to the very large number of broadcasting stations in all parts of the world now coming into operation on wavelengths below 50 metres or so. It is only right that short-wave reception should be popular, because the very simplest type of receiver is sufficient to provide good loud speaker signals from stations situated thousands of miles away. And, moreover, conditions are much better on the short waves, since the bugbears of interference—heterodyning and the like—are practically non-existent.

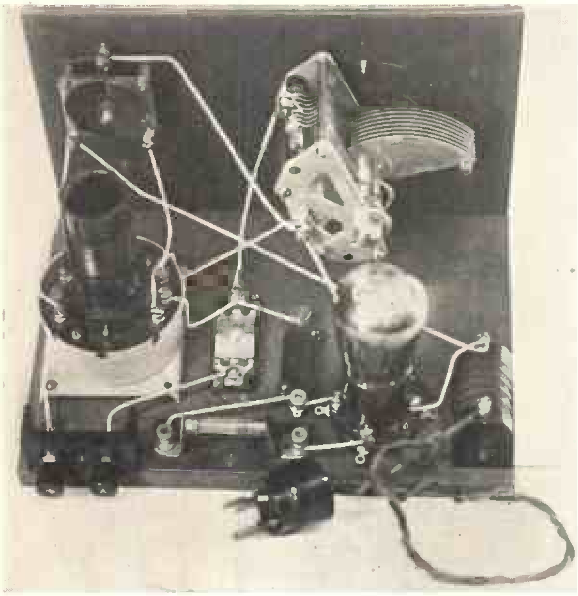


Fig. 1.—LAYOUT OF A TYPICAL SHORT-WAVE ADAPTOR.

Perhaps the greatest deterrent to the more general use of short-wave transmissions as a source of entertainment is that they cannot be received on the ordinary broadcast set. There is, however, a very simple and inexpensive means of overcoming this difficulty, and it consists of using a single-valve S.W. adaptor or converter in conjunction with the existing set.

Adaptor or Converter

The terms " adaptor " and " converter " are frequently confused in the mind of the amateur. An adaptor is a single valve short-wave receiver which replaces the detector valve of the broadcast set and works in conjunction with the low-frequency stage or stages as a two- or three-valve receiver. A converter, on the other hand, is a single-valve *oscillator* which operates in conjunction with the whole set and so converts it into a S.W. superheterodyne. A converter will, as a general rule, give better results than does an adaptor, but it can only be employed with a receiver having at least one high-frequency (S.G. or V.-M.) amplifying valve.

A Short-Wave Adaptor

Let us start by examining the circuit of an adaptor such as that shown in Fig. 2. The general arrangement is the same as that of a detector valve in any normal Det.-L.F. set. A two-range short-wave tuner is employed, but that might be replaced by plug-in coils if desired ; rectification is on the leaky grid principle, and a high-frequency choke is connected in the anode circuit of the detector valve.

How the Adaptor is Connected to the Set

Connection between the adaptor and the set is made through a valve plug, which may be bought from such firms as Messrs. Bulgin or made from the base of an old valve. The end of the high-frequency choke is connected to the plate or anode pin, whilst the two low-tension leads are joined to the filament pins. In use, the detector valve, aerial and earth leads are transferred from the set to the adaptor, the valve being replaced by the plug. By following this method the on-off switch in the set is also operative on the S.W. valve, and so the need for a second switch is obviated.

Low-Tension Leads Must be Connected Correctly

There is just one precaution which must be taken, and this is to see that the low-tension leads of the adaptor are so connected to the valve plug that they are given correct polarity; that to which the grid leak is connected must go to L.T. positive. This point is made clear on the diagram of Fig. 2, where the leads are appropriately marked with positive and negative signs.

If there is any difficulty in tracing the polarity of the filament wires in the set the correct connections can easily be found by trial. After connecting up, all tuning is done on the adaptor and no alterations of any kind need be made to the set.

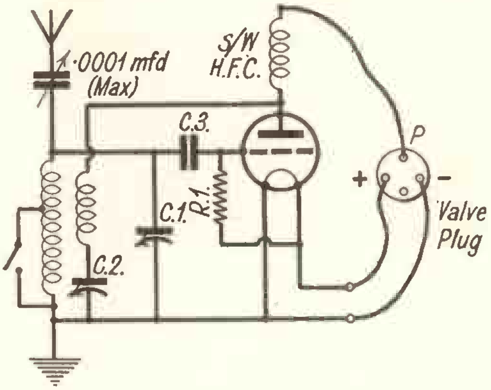


Fig. 2.—The Circuit of a Short-wave Adaptor.

Values of components are as follows:—
C_1, ·00015 mfd. to ·0002 mfd. fitted with slow-motion dial and extension spindle; C_2, ·0001 mfd. to ·0003 mfd.; C_1, ·00005 mfd. to ·0002 mfd. (reset for preference); R_1, grid leak, 5 megohms.

A Short-Wave Converter

We can now consider the circuit for a converter shown in Fig. 3. The tuning and reaction arrangements are identical with those of Fig. 2, but it will be seen that two high-frequency chokes, as well as a ·0002 mfd. fixed condenser, are connected in the anode circuit of the valve. The first choke is of the short-wave pattern, but the second is a component of the type used in a normal broadcast receiver. As explained before, the valve functions as an oscillator, and its purpose is to change the short-wave signals into long-wave ones which can be amplified and rectified by the receiver. It must be taken for granted that the valve *does* change the wavelengths of the signals, and so the ordinary H.F. choke is used in conjunction with the fixed condenser to provide choke-capacity high-frequency coupling between the converter and the first valve in the receiver. A full description of the principle of a short-wave converter appears on p. 372.

Connections to the Set

The lead marked "H.T.+" must be connected to a suitable voltage tapping on the high-tension battery; aerial and earth leads are transferred to the converter, and the wire from the fixed condenser is connected to the aerial terminal on the set; both low-tension leads are connected to the corresponding terminals on one of the valve holders in the set. An additional valve is required for the converter and this may be either a type "H." or "H.L."

Method of Operation of a Converter

The method of operation is quite different to that employed in the case of an adaptor. For one thing the valve must always be maintained in a state of oscillation, otherwise nothing will be heard. All tuning is done on the converter after the receiver has once been adjusted to its best position, which will generally prove to be between 500 and 1,500 metres. The reaction knob on the set is used for its normal purpose of controlling volume, and, despite the fact that the converter valve is always oscillating, carrier wave "squeaks" will not be heard unless the set is also in a state of oscillation.

Special S.W. Receivers

Although the methods of using an ordinary set for short-wave reception mentioned above are perfectly satisfactory, they have the disadvantage that the extra unit must be disconnected when the set is required for its normal purpose. For this reason there are many points in favour of the use of a special short-wave receiver which is complete in itself and which can be experimented with and used quite independent of the broadcast set.

The Simplest S.W. Set

The circuit diagram of a very good and ultra-simple Det.L.F. two-valve S.W. receiver is shown in Fig. 5. The first valve is connected exactly like that of the adaptor represented by Fig. 2, but is followed by a transformer-coupled low-frequency amplifier. A set of this kind will give excellent phone reception over unlimited distances and will, under good conditions, provide loud speaker signals from quite a number of stations.

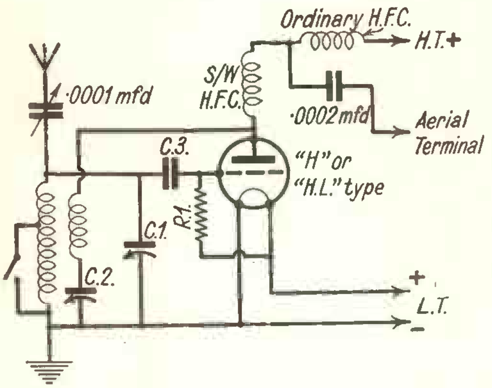


Fig. 3.—CIRCUIT OF A SHORT-WAVE CONVERTER.

Values of components are the same as those shown under Fig. 2.

Improvements that can be Introduced

This type of set lends itself very well to numerous refinements, some of which are indicated in Fig. 6. Let us examine these refinements and consider the object of each. In the first place it will be observed that the fixed grid condenser (C.3) has been replaced by a variable one (preferably of the pre-set type), and careful adjustment of this will often improve reaction control to a noticeable extent.

Preventing Uncontrollable Oscillation

A 200-ohm resistance has been connected in series with the reaction winding of the tuner to prevent uncontrollable oscillation which is sometimes experienced at certain wavelengths. This resistance must be non-inductive, and one of the metallised type is most convenient. Its exact ohmic value is not critical, and anything between 100 and 500 ohms will be suitable in most cases. If care is taken in choosing the resistance it should be possible to obtain a more or less uniform degree of reaction over the whole range of the tuning condenser with substantially the same setting of the reaction control.

The Potentiometer

It is usual to connect the grid leak direct to L.T. positive, but better results can sometimes be obtained by taking it to the negative lead instead. So as to obtain either a positive, negative or intermediate grid potential at will, the grid leak is joined to the slider of a 250-ohm potentiometer, of which the ends are connected across the L.T. source. Adjustment of the potentiometer is very useful in obtaining perfectly steady reaction control, which is of more importance than anything else in D.X. (or long distance) reception.

It is generally advisable to connect a ·001 mfd. fixed condenser between the grid leak and earth, as shown in broken lines on Fig. 6, so that no restriction is offered to the easy flow of high-frequency currents.

What the High-Frequency Choke Does

The object of the high-frequency choke connected in the anode circuit of the detector valve is to prevent the passage of H.F. or signal currents into the amplifier. When dealing with signals on longer wavelengths the choke performs this function perfectly well in the majority of cases, but short waves are somewhat more difficult to control with a result that a certain amount

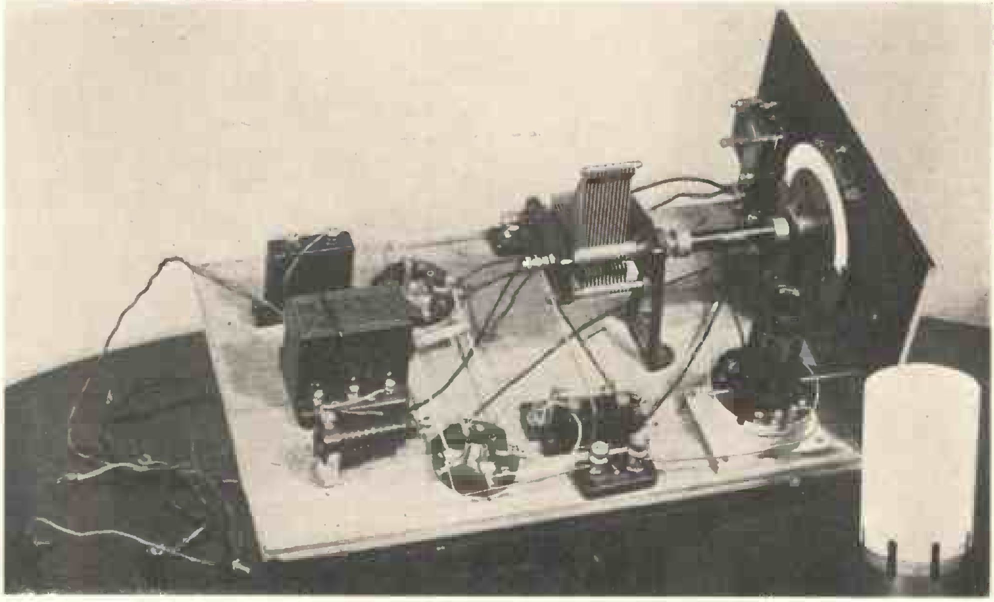


Fig. 4.—LAYOUT OF A TYPICAL TWO-VALVE SHORT-WAVE RECEIVER.

of high-frequency " leakage " often occurs across the choke.

Why a " Stopper " Resistance should be Used

When such leakage does take place, and no precautions are taken to prevent its effects, the receiver becomes very " sensitive " to the presence of the operator (referred to as hand capacity) and reception is often marred, or even prevented, by various " howls " and " groans." Therefore it is always well to connect a " stopper " resistance between the secondary winding of the low-frequency transformer and the grid of the second valve. The resistance should be a non-inductive one of from 50,000 to 250,000 ohms, and its purpose is to bar the passage of H.F. currents, whilst providing an easy path for L.F. or audio-frequency impulses.

Fixed Condenser between Anode of second Valve and Earth

Another refinement indicated in Fig. 6 is to connect a ·002 mfd. fixed condenser between the anode of the second valve and earth. The object of this condenser might appear a little obscure at first ; it is to provide an easy leakage path for any H.F. currents which might find their way into the anode circuit. Impossible as it might appear on first thoughts, H.F. currents *do* very often get into this circuit, either by leakage across the " stopper " resistance or by direct pick-up from the phone or loud speaker leads.

A Cure for Troublesome Hand-capacity Effect

Even after all the precautions hitherto referred to have been taken, it is not by any means unusual to find that hand-capacity effects are troublesome when tuning in a weak signal. These latter are evidenced by the fact that, after having been properly tuned in, signals disappear or become weaker immediately the hand is removed from the tuning knob. The difficulty referred to is most common when phones are being used for reception, but is not unknown even when listening on a speaker. Provided that the general design of the set is on sound lines a cure can generally be effected by inserting a high-frequency choke between the anode of the last valve and the corresponding phone or loud speaker terminal. The choke should, for preference, be of a short-wave type, but a good one of normal pattern will often serve the purpose.

A receiver embracing all the features referred to above will afford splendid results, and once adjusted will be almost as easy to operate as the average "family" broadcast set. It should also be pointed out that, whilst the modifications have been suggested in regard to one particular instrument, they are equally applicable to practically any S.W. receiver or adaptor. Some of them might also be applied to a converter, but they should not normally be necessary, since the converter is very stable and does not require such delicate adjustment.

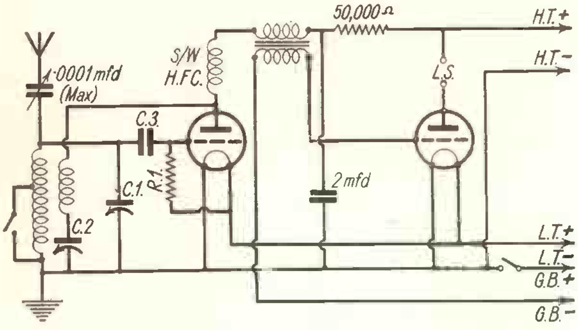


Fig. 5.—Circuit of a Simple Two-valve Short-wave Receiver.

A Screened-Grid Circuit for Short Waves

A screened-grid valve does not provide very much amplification on short waves, but it is extremely useful in other ways. The principal advantage of the S.G. valve is that it isolates the aerial from the main tuning and reaction circuits, and by so doing makes possible a considerable improvement in reaction control.

Aerial Circuit is Untuned

Fig. 8 shows the circuit of a tested and proved three-valve S.G. short-wave receiver; let us trace it through and observe any unusual features. First of all we find that the aerial circuit is untuned and consists only of a high-frequency choke or 250,000-ohm non-inductive resistance. Naturally, this aperiodic tuning is not quite so efficient as an accurately tuned circuit, but is much more "workable," because if a second tuning condenser were introduced it would have to be operated simultaneously with that tuning the grid circuit of the detector valve, and operation of the set would become very difficult in consequence.

When a choke is used it should be either a special short-wave component, or otherwise one of the "universal" type designed for operation on either long or short waves. A good choke is better than a resistance in most cases, but the latter is nevertheless quite satisfactory.

The Coupling System

The S.G. valve is connected to the detector through a high-frequency transformer of which the secondary is tuned. Reaction is applied through a separate winding on the transformer and a variable condenser. Coupling could be on the tuned anode or tuned grid systems, which are more popular in receivers for the higher wavelengths, but the transformer method is found to be appreciably better for several reasons which we need not discuss in this article.

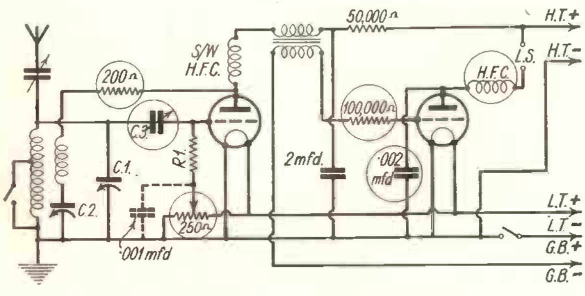


Fig. 6.—A Similar Circuit to Fig. 5.

The addition of several refinements is indicated by circles.

Normal grid leak rectification is employed and the detector feeds the L.F. valve (a pentode is shown) through a transformer. The detector anode circuit is de-coupled in the usual way by means of

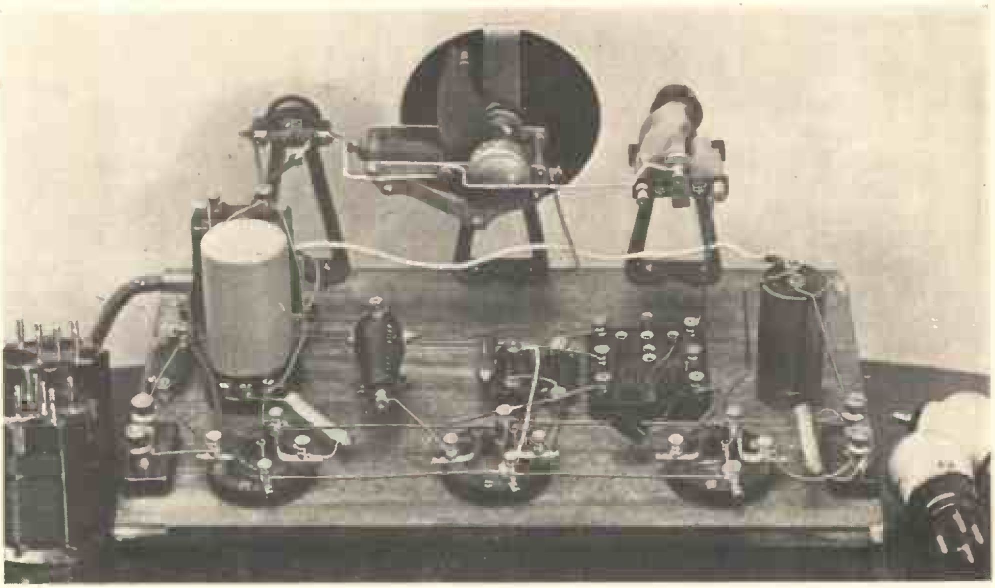


Fig. 7.—A Three-valve Short-wave Receiver.

This is a S.G.-Det.-L.F. set using plug in H.F. transformers and may be used for ordinary broadcast reception if desired.

a 50,000 ohm resistance and 2 mfd. condenser. A "stopper" resistance is included in the grid lead to the pentode, and any H.F. currents appearing in the anode circuit are by-passed to earth through a ·002 mfd. fixed condenser.

The circuit given in Fig. 8 might be modified by introducing some of the refinements shown in Fig. 6, but, generally speaking, these will not be required because of the inherent stability of the arrangement as it stands.

The Choice of Components

So far no reference has been made to the type of components required for a short-wave set.

Short-Wave Tuners

In the circuits of Figs. 2, 3, 5 and 6 the use of a ready-made dual- or triple-range S.W. tuner of the type made by Messrs. Lissen, Colvern, R.I, Telsen, etc., has been assumed. All the makes of tuners mentioned can be obtained complete with wavechange switch.

The High-Frequency Transformers

High-frequency transformers of the 6-pin type, such as are recommended for the circuit of Fig. 8, can be obtained from Messrs. Stratton & Co., makers of "Eddystone" short-wave components.

Data for Winding Suitable Coils

When desired, tuning coils of the plug-in type can be made fairly easily by winding the requisite number of turns of 16's or 18's gauge wire round a short length of 2½-inch diameter tube and attaching them to a mount as shown in Fig. 9. For the aerial coil the approximate numbers of turns for 15, 30 and 50 metres are 3, 6 and 9 respectively. For reaction, similar or rather smaller coils may be used and mounted near, and parallel to, the aerial coil.

The Series Aerial Condenser

In the case of any non-S.G. receiver it is very desirable that a small variable or pre-set condenser should be connected in series with the aerial lead; it should have a maximum capacity of ·0001 mfd. or less, and should be so adjusted that oscillation can easily be obtained on any waveband. If this condenser were omitted, it is more than probable that the set would fail to oscillate, due to the heavy "damping" caused by the aerial.

The Variable Condensers

The variable condensers marked C.1 and C.2 are very important components, and should always be of a low-loss type specially designed for S.W. work. The tuning condenser C.1 should have a capacity of from ·00015 mfd. to ·0002 mfd., and should preferably be fitted with a slow-motion dial and extension spindle. Condenser C.2, which is used for reaction control, may have any capacity between ·0001 mfd. and ·0003 mfd., but when the capacity is greater than, say, ·00015 mfd., a slow-motion or vernier drive should certainly be employed. All those points raised in connection with variable condensers in general, in the article on p. 531, apply even more particularly to condensers for use in short-wave receivers.

The Grid Condenser

The grid condenser marked C.3 may have any capacity between ·00005 mfd. and ·0002 mfd.; ·0001 is a good average value. Where convenient, however, it is wise to employ a pre-set condenser so that the optimum capacity may be found experimentally. The grid leak R.1 should for preference have a higher value than is usual in a broadcast set, and best results are generally given by a resistance of some 5 megohms.

The question of high-frequency chokes was fully dealt with on p. 767.

Choice of Valves

As with any type of receiver, the correct choice of valves is a matter of some importance. The detector is, of course, the one which has most effect on the general operation of the set, and for this position it is generally best to employ a valve of the high-impedance pattern, such as a type "H" or "H.L.," although one of those specially made for detecting and styled "210 Det." or "2DX" will work fairly well in a short-wave receiver. It is sometimes found even better to use a screened-grid valve for detector, and suitable connections are shown in Fig. 10; the only difference is that a separate high-tension supply voltage is required for the screening grid and is obtained through a 100,000-ohm potentiometer, a ·1-mfd. non-inductive condenser being used to by-pass high-frequency currents.

For the screened-grid stage of a set like that represented by Fig. 8, any type of high-amplification S.G. valve (for example, Cossor "215 S.G." or Mullard "P.M. 12") will serve admirably.

In the L.F. stage one of the newer types of high-amplification power valves like the Cossor "220 P.A." and Mullard "P.M. 2A" will be found most efficient. Any other kind of power valve could, naturally, be employed, but it would not provide quite so much volume on more distant stations.

L.F. Transformer

The valves used for the detector and L.F. positions will influence the choice of a low-frequency transformer. The latter

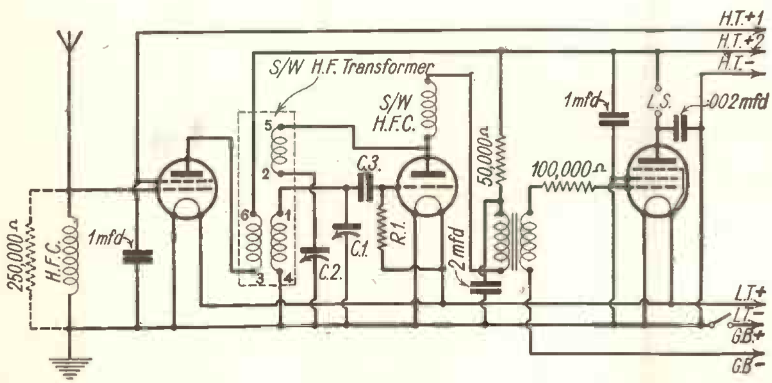


Fig. 8.—The Circuit of the Three-valve Short-wave Receiver. The numbered connections on the H.F. transformer refer to the particular component mentioned in the text.

component should have a high primary impedance when the detector is a type "H.," "H.L." or "S.G.," but a lower impedance will be suitable in the case of most other valves. The step-up ratio should not be greater than about 4 : 1 when using one of the power valves suggested above, although a ratio up to 7 : 1 is somewhat better for ordinary low-amplification valves.

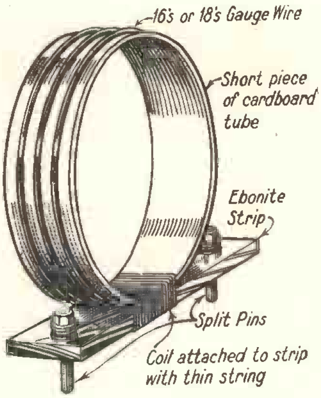


Fig. 9.—A Simple Method of Construction for Short-wave Plug-in Coils.

H.T. and G.B. Voltages

These will naturally depend entirely on the valves in use and it is impossible to give any definite figures. For a converter of the kind represented by Fig. 3 the optimum high-tension voltage will generally lie between 60 and 80, but in the case of those circuits shown in Figs. 5, 6 and 8 the voltage should not be less than 100, whilst better results will be obtained by increasing this up to 120. Tapping "H.T. + 1" in the circuit of Fig. 8 should receive a voltage equal to about two-thirds that supplied to "H.T. + 2," that is, about 80 volts when using a 120-volt battery, or 66 volts where the battery is of 100 volts.

In all cases the G.B. voltage should approximate to that specified by the valve manufacturers for the H.T. voltage in use.

A Point about the Wiring

It is also important that the wiring and, in fact, the whole of the constructional work should be as rigid as possible, since any vibration would be liable so to affect the stray capacities that accurate tuning would be impossible. Perfect insulation must be ensured because any slight defects in this regard will result in very serious losses; for this reason only the very best and most reliable makes of components should be chosen. It is quite safe to use a wooden panel so long as all parts coming in contact with it are at earth potential.

The Adaptor and the Converter

It is not the object of this article to give specific designs, but rather to offer such suggestions as will prove of assistance in enabling the experimenter to decide on the most suitable form of receiver for his special requirements and to work out his own constructional details. Fig. 1 shows a simple short-wave adaptor using a circuit similar to that of Fig. 2; it will be seen that the lay-out and wiring are particularly simple and entirely devoid of "frills"; the particular tuner illustrated is the Colvern KSW, but any of those mentioned previously could be used in a similar manner; a special "Lotus" ·00015 mfd. short-wave condenser, fitted with slow-motion drive, is employed for tuning, and a ·0001 mfd. differential condenser is used for reaction control. The very same lay-out would be equally applicable to a short-wave converter of the type represented by the circuit of Fig. 2.

THE CONSTRUCTION OF S/W RECEIVERS

The principles underlying the general design and component lay-out of short-wave receivers are essentially similar to those applying in the case of a broadcast set. Greater care must be taken, however, to reduce unwanted capacity effects by keeping all wires in the grid and anode circuits as far apart as possible.

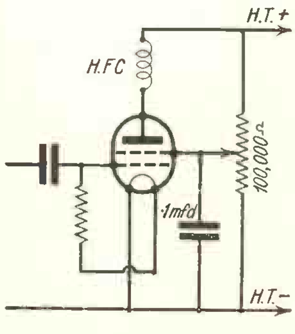


Fig. 10.—How the Screened-grid Valve may be Connected for use as a Detector.

The Two-valve Receiver

Fig. 4 shows a two-valve S/W receiver using a circuit not unlike those of Figs. 5 and 6. In this case a tuning condenser having an extension spindle is employed, so as to minimise hand-capacity effects. The condenser is adjusted through the medium of a vernier disc drive giving a reduction ratio of about 20 : 1, which proves very convenient in practice. Notice that all components are well spaced, but are at the same time in such positions that a minimum amount of wiring is necessary.

The Three-valve Receiver

A three-valve S.G. receiver is illustrated in Fig. 7, and it uses the circuit of Fig. 8. This receiver is built up in experimental form, and so as to make all the components very accessible the usual panel has been dispensed with, tuning controls being mounted on aluminium brackets. As it employs " Eddystone " 6-pin plug-in H.F. transformers, this set can also be used on the broadcast bands by substituting appropriate transformers (actually the type " 2G " for 260 and 550 metres and the " 2GY " for 900–1,800 metres).

Aluminium screening plates are not used in any of the sets illustrated, nor are they necessary so long as a good earth lead is employed and the *moving* plates of variable condensers connected to earth. Although the receivers represented by the three photographs are more or less " standardised " designs, they may be modified in numerous ways to make use of components which the constructor might have on hand ; so long as the general component positions are followed, no great difficulty should be anticipated in building up an efficient short-wave instrument.

Best Type of Aerial to Use

Although the ordinary aerial may be employed for short-wave reception it is better to use a short wire no more than 40 feet or so in total length. Even an inside aerial will often give better results than a long outside one, but the ideal is achieved by erecting a single vertical wire about 30 feet long. When working on wavelengths below about 20 metres the best results can very often be obtained from a short vertical wire extending from the aerial terminal of the set to the ceiling. In any case, it is well worth while to experiment with a few aerials of different types.

Good Earth Connection is Essential

A really good connection to earth is of special importance in S.W. work and a long lead should be avoided at all costs. Quite often it is found that better results can be obtained when the earth lead is disconnected, but this invariably indicates that the connection is of high resistance and therefore inefficient. When it is impossible to obtain a short direct earth lead, it is a very good plan to use a " counterpoise " consisting of an insulated wire running below the aerial and some distance away from it. This should, of course, be connected in place of the earth lead which it replaces.

Tuning a Short-Wave Set

Fundamentally, the operation of a short-wave set is not much different to that of a broadcast receiver, but all adjustments must be made more delicately and with a greater degree of accuracy. This point will be more fully appreciated when it is explained that the " tuning spread " of a station on 30 metres does not exceed half a degree on the dial of a ·00015 mfd. condenser. From this example it will be obvious that a slow-motion tuning dial is practically essential.

Reaction Control is Critical

Reaction control is critical, and it is well worth the necessary time carefully to adjust the pre-set aerial condenser, grid leak, potentiometer and grid condenser to such positions that the set goes into, and out of, oscillation smoothly and without any sign of a " plop " or " click." The accurate adjustment of high-tension voltage makes a big difference to reaction smoothness, and the effect of different voltages should be tried whilst carrying out other alterations.

How Oscillation is Indicated

Oscillation is indicated by a faint " breathing " or " rushing " sound. The receiver is most sensitive when *just off* the point of oscillation.

THE DOUBLE PUSH-PULL RECEIVER

By EDWARD W. HOBBS, A.I.N.A.

PURE reproduction free from distortion is the distinguishing feature of the novel receiver, shown complete in Fig. 1.

To attain the end in view necessitates especial care with the detector stage, so that it can be relied upon to deal faithfully with every subtle modulation of speech and music.

Pure Reproduction

This problem of distortionless reproduction has been tackled by various designers in many different ways, but in the present set a solution has been sought and largely realised in the use of a push-pull detector, developed by the B.B.C. engineers, followed by push-pull amplification, an arrangement necessitating four valves.

At the outset it should be pointed out that more orthodox arrangements of four valves, such as those described in the section on "Tested Circuits," will give greater range and volume of sound, but in this design the paramount considerations have been sweetness and purity of reproduction, both on radio and gramophone records.

Simple Circuit

The circuit given in Fig. 2 is quite simple and straightforward, but there are several matters that require special attention when translating it into actuality.

The aerial input circuit is magnetically coupled to the tuned grid circuit ; reaction is obtained by the variable resistance method, and both detector valves are transformer coupled to the push-pull output stage. The loud speaker is choke-capacity fed.

Practical Considerations

On the face of it, the circuit does not present any difficulty, but in practice the best results will only be obtained by paying particular attention to the layout and wiring up of the components.

The set here described and illustrated gives entirely satisfactory results, with ample volume for normal domestic use. The current consumption is pleasingly low —about 8 m.a. during normal reception.

Why Double Push-Pull is Used

Two push-pull stages are used because this form of detection gives high quality results ; a push-pull output stage with two pentodes is used because it provides ample volume on a minimum current consumption, and is especially responsive to relatively weak inputs ; distortion due to overloading is thereby reduced to a minimum ; furthermore, second harmonics are cancelled out.

Finally, the use of choke-capacity fed dual-balanced loud speakers, housed in a "Howe" box baffle ensures the most realistic reproduction that can be hoped for at the present stage of technical advancement.

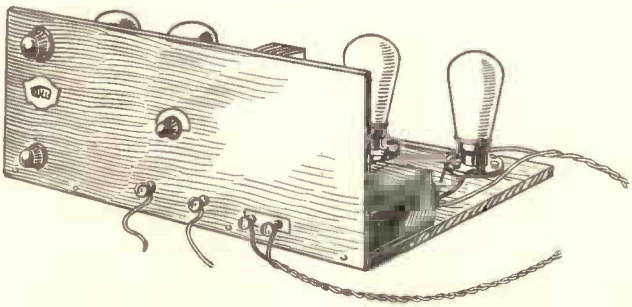


Fig. 1.—THE FINISHED "DOUBLE PUSH-PULL" RECEIVER.
The set is remarkably simple and can be fitted readily into any cabinet, either for radio reception or gramophone record reproduction.

Components and Materials Required

The following commercial components are required for the "Double Push-Pull," but, in addition, there are several that must be made specially, as explained later :—

BASEBOARD.—Plywood, $\frac{3}{8}$ inch thick, 10 inches wide, 14 inches long.

PANEL.—Plywood, $\frac{1}{8}$ inch thick, $6\frac{1}{2}$ inches wide, 14 inches long.

COIL MATERIAL.—Coil Former, $2\frac{1}{4}$ inches diameter, $2\frac{1}{2}$ inches long (" *Becol* ") ; Wire, $\frac{1}{2}$ oz. No. 32, D.S.C. (" *Lewcos* ").

CONDENSER.—1 ·0005 mfd. " Low Loss " (" *Lissen* ") ; 1 Illuminated slow-motion dial (" *Jackson Bros.*").

PRE-SET CONDENSER.—1 ·0005 mfd. " Pre-Set " No. 2 (" *Igranic* ").

GRID LEAK.—1 $\frac{1}{2}$-megohm wire wound (" *Dubilier* ").

SWITCH.—1 No. 8720 D.P.D.T. (" *Benjamin* ").

EBONITE PLATE. — 1 piece $\frac{3}{32}$ inch thick, 2 inches wide, 8 inches long (" *Becol* ").

CHOKE.—1 Screened type, No. H.F.P. (" *Wearite* ").

VALVE HOLDERS.—2 4-pin, 2 5-pin (" *Telsen* ").

VARIABLE RESISTANCE.—1 10,000 ohms non-inductive (" *Rotor ohm* ").

TRANSFORMER.—1 No. AF5C (" *Ferranti* ").

OUTPUT CHOKE.—1 No. LF17 (" *Bulgin* ").

FIXED CONDENSERS.—2 2-mfd., Type 80 (" *T.C.C.*") ; 1 ·0001-mfd. (" *T.C.C.*") 1 ·005-mfd. (" *T.C.C.*").

FIXED RESISTANCES.—1 250,000 ohms ; 1 50,000 ohms (" *Erie* ").

BATTERY CORD.—1 7-way with " Wanderfuse " (" *Belling-Lee* ").

TERMINALS.—1 " LS " ; 1 " PU " twin socket strips, No. 1047 ; 1 each " A," " E," Type R (" *Belling-Lee* ").

VALVES.—2 No. L2, metallised ; 2 No. 220 Pen. (" *Mazda* ").

BATTERIES.—1 2-volt L.T. Gel-Cel, No. JWF7 (" *Exide* ") ; 1 H.T., No. 1012, Drydex (" *Exide* ") ; 1 G.B., No. 1001, Drydex (" *Exide* ") ; 1 G.B., No. 1002, Drydex (" *Exide* ").

LOUD SPEAKER.—1 matched pair F5 PM " Rola," or 1 PM No. M3T (" *Ferranti* ").

BOX BAFFLE.—1 special dual kit (" *F. McNeil & Co. Ltd.*").

WIRING.—2 coils " Glazite," 6 yards " Lewcoflex " (" *Lewcos* ").

DIAL LIGHT.—1 2-volt, 12-milliampere type (" *Bulgin* ").

What to do First

Begin by marking out the panel as in Fig. 3, drilling the holes for the various components and then screwing it to the baseboard. Next mount the components on the baseboard, as shown in Fig. 13, so far as they are at present available, then fix the L.T. wiring, as shown in Fig. 4, and wire up the switch. Next fit wires from the two loud speaker sockets to the two 2-mfd. condensers, which may temporarily be removed to allow this to be done.

Importance of Layout

Correct layout and wiring are very important for this set, as unless it is properly done the results will be very poor.

Since it is desirable to know why this is so, consider for a moment the peculiar way in which the push-pull detector operates.

Action of Push-Pull Detector

The tuned input circuit is connected directly to the grids of the two valves, as shown in simplified form in Fig. 5 ; hence the applied voltages on the grids are 180 degrees out of phase, and the voltage applied between the grid and filament of each valve is half the total voltage.

Rectification takes place in the grid circuit of each valve, the rectified voltage being produced across the grid leak.

Rectified Voltages in Phase

The rectified voltages are, however, in phase, but as the two anodes are connected in parallel the high-frequency voltages cancel out in the common anode circuit.

Stated simply, each valve has to do only half the work of a normal detector, hence distortion due to the grid volt swing is practically eliminated while the cancelling out of unwanted H.F. voltages eliminates a potent source of trouble.

Resistance Controlled Reaction

Reaction cannot be obtained by the usual capacity method because there is no

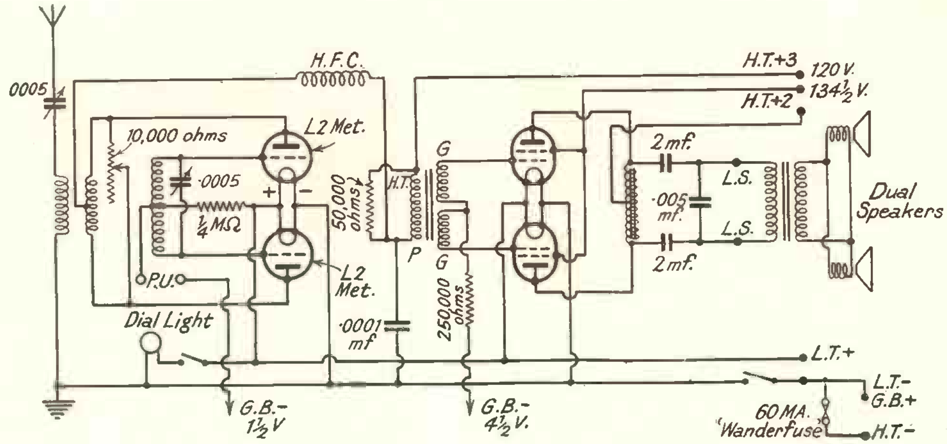


Fig. 2.—Circuit of the "Double Push-Pull" Receiver.

A push-pull detector followed by push-pull amplification ensures the most realistic tonal quality.

appreciable H.F. current flowing in the anode circuit, but by using a centre-tapped coil with a variable resistance shunted across it, a very smooth reaction control is obtained, the total value of which can be kept low—just sufficient to reduce the damping of the tuned circuit.

Reduced Damping

The push-pull arrangement minimises the damping effects on the tuned circuit, most of them cancelling out, consequently a smaller amount of reaction is required, with a consequent lowering of the risk of amplitude distortion.

Brief consideration of these and other related facts will show that while such an arrangement offers great possibilities, it possesses a number of practical pitfalls.

Equality of Applied Voltages

To begin with it is essential that the valves be fairly closely matched as regards their characteristics and performance. Secondly, the voltages applied to the grids must be as nearly equal as possible, hence each grid must have the same capacity to earth. The tapped-grid coil must be mechanically and electrically symmetrical about the centre tapping.

Furthermore, the reaction windings and the aerial primary winding must be so arranged that they are—so far as practicable—electrically symmetrical about the grid coil.

To ensure all these qualities necessitates a specially wound coil, well spaced components and a symmetrical arrangement of wiring.

The great thing to avoid is any unbalanced capacity in the wiring, for which reason all corresponding wires of any pair should be of equal length and arrangement.

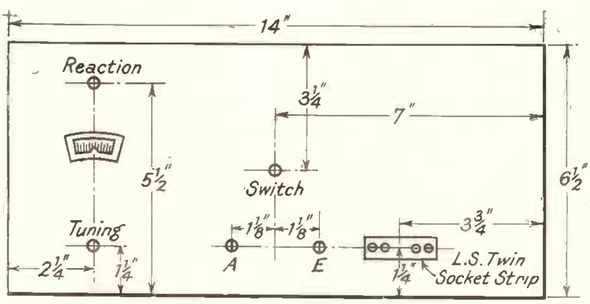


Fig. 3.—Layout of Panel.

Arrangement of components on panel as seen from the front.

Obviously an ordinary tuning condenser is badly out of balance, the moving plates and frame having more capacity than the fixed plates, hence the use of a special condenser, described later in detail.

(P26)

Reverting now to practical constructional work, proceed to alter the condenser to fit it for its special duties.

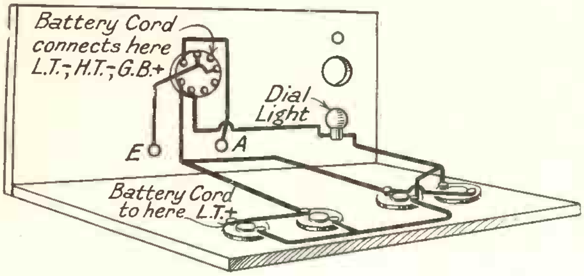


Fig. 4.—L.T. and Switch Wiring.

The switch controls battery supply, also the dial light. When switch is to the left, as seen from the back, set is "off" and aerial is earthed; in mid position set is "on"; in right position dial light is switched on for tuning. Normally, use the mid position for "on."

Adapting the Condenser

Practically speaking, all that has to be done is to remove every possible bit of unwanted metal, and leave only the fixed and moving vanes with the spindle. In practice it suffices to remove the two side frames and replace them with others made of ebonite or bakelite. Use the metal side frames as templates, and take care to drill all holes in exactly corresponding places in the ebonite, then re-assemble the condenser and fix it with an ebonite bush and nut to the slow-motion device, following the instructions given on the sheet supplied with dial.

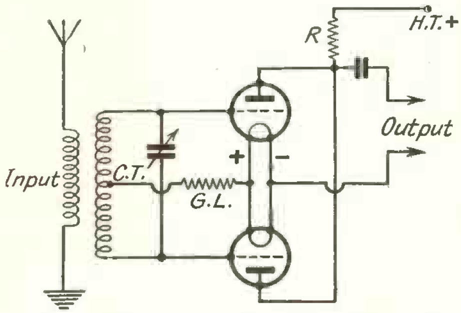


Fig. 5.—Simplified Push-Pull Circuit.

This shows the elements of the push-pull detector circuit, without reaction.

Test carefully to see that the condenser vanes have not been distorted during the change, also connect the metal cross bars to the fixed plates; they are about equal in capacity to the moving spindle and help to ensure a good balance. The appearance of the condenser when altered is clearly shown in Fig. 6.

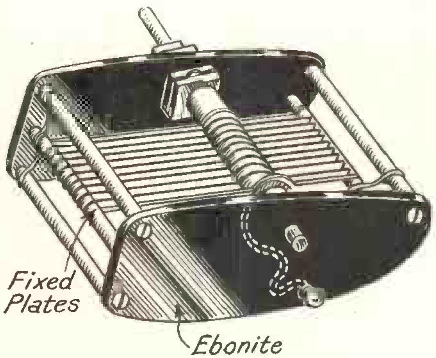


Fig. 6.—Special Condenser.

The metal side plates are replaced with ebonite or bakelite; the cross-bars are connected to fixed plates.

Winding the Coil

The coil is wound throughout with No. 32 D.S.C. wire, all windings in the same direction. Begin by winding the grid coil, take care to have the start, finish and centre tap all on the same axial line.

Next wind the reaction windings, bringing the ends of the windings and the centre tap out on the opposite side of the coil, but all in the same axial line, as shown in Fig. 8, which gives all necessary details. Finally, wind the aerial primary coil and bring the two ends out at right angles, allow sufficient wire for connections, and refer to the article on coil winding on pp. 381 to 392 for details of the winding processes. Make all windings as even and uniform as possible, and terminate them at small screws driven into the ebonite former.

Wiring the Detector Circuit

Now fix the coil in place on the baseboard with three small screws and proceed to wire up the detector circuit only. The wires that are involved are all shown clearly in Fig. 9, and this arrangement should be carefully copied.

Having done this, the detectors can be tested and adjusted before proceeding with the L.F. amplifier, as by this means any troubles that may arise can be dealt with summarily.

Testing the Detector

To test the working of the detector add the wires and connect up the batteries and a pair of headphones, as shown in Fig. 10, connect the set to aerial and earth, switch on and tune in the local station.

It will be found that the selectivity is much better than with the usual single grid-leak detector, and, by careful adjustment of the aerial pre-set condenser, sufficient selectivity will be obtained to separate completely the local station. If not, the aerial primary winding may be reduced to only a few turns, preferably of thicker wire, say No. 20 gauge.

Before doing this, however, endeavour to tune in a station at the lower end of the scale and another at the high end of the scale. Reaction is very smooth; there should not be any of the familiar "howls" when tuning.

Take particular note of any ten-

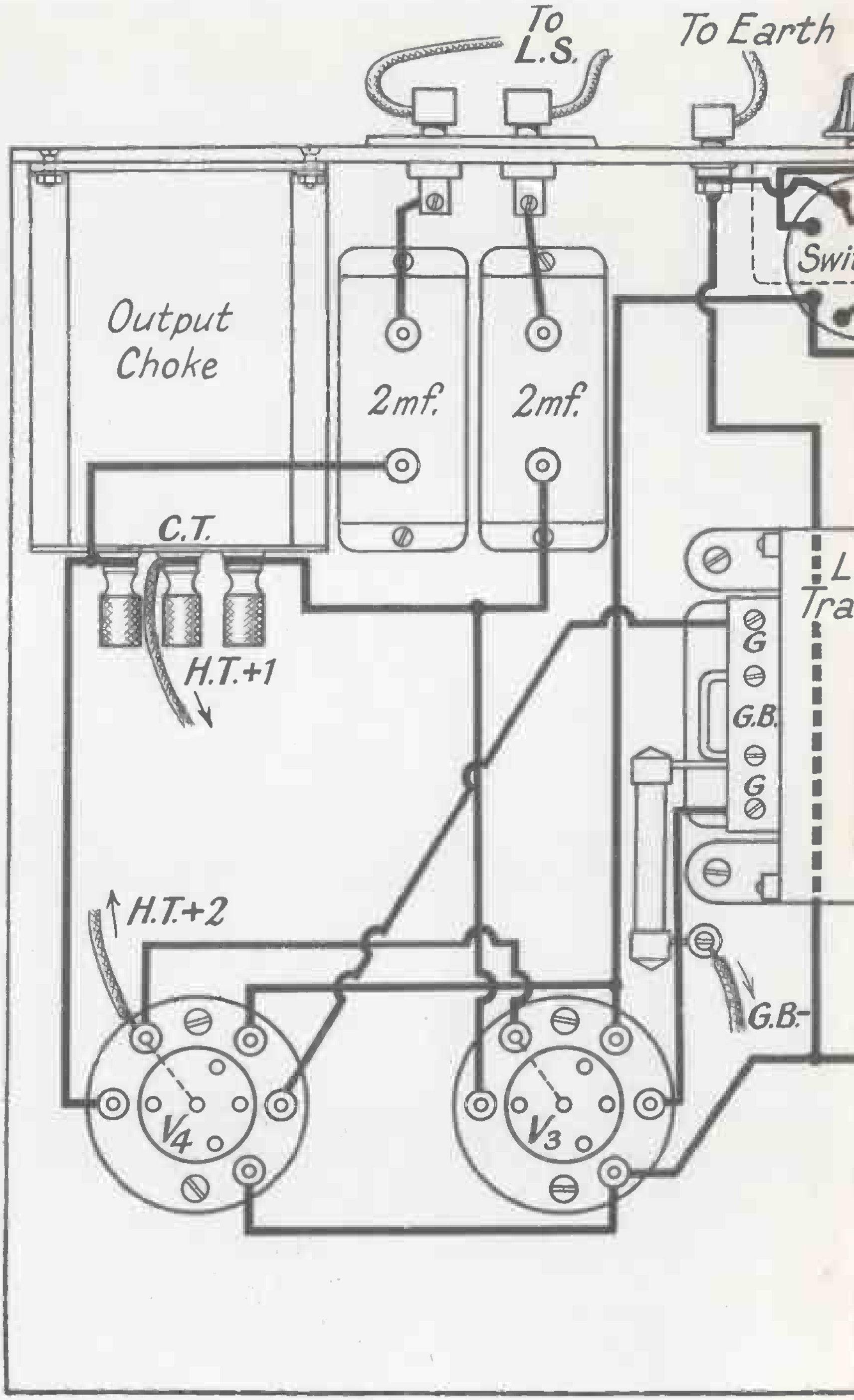
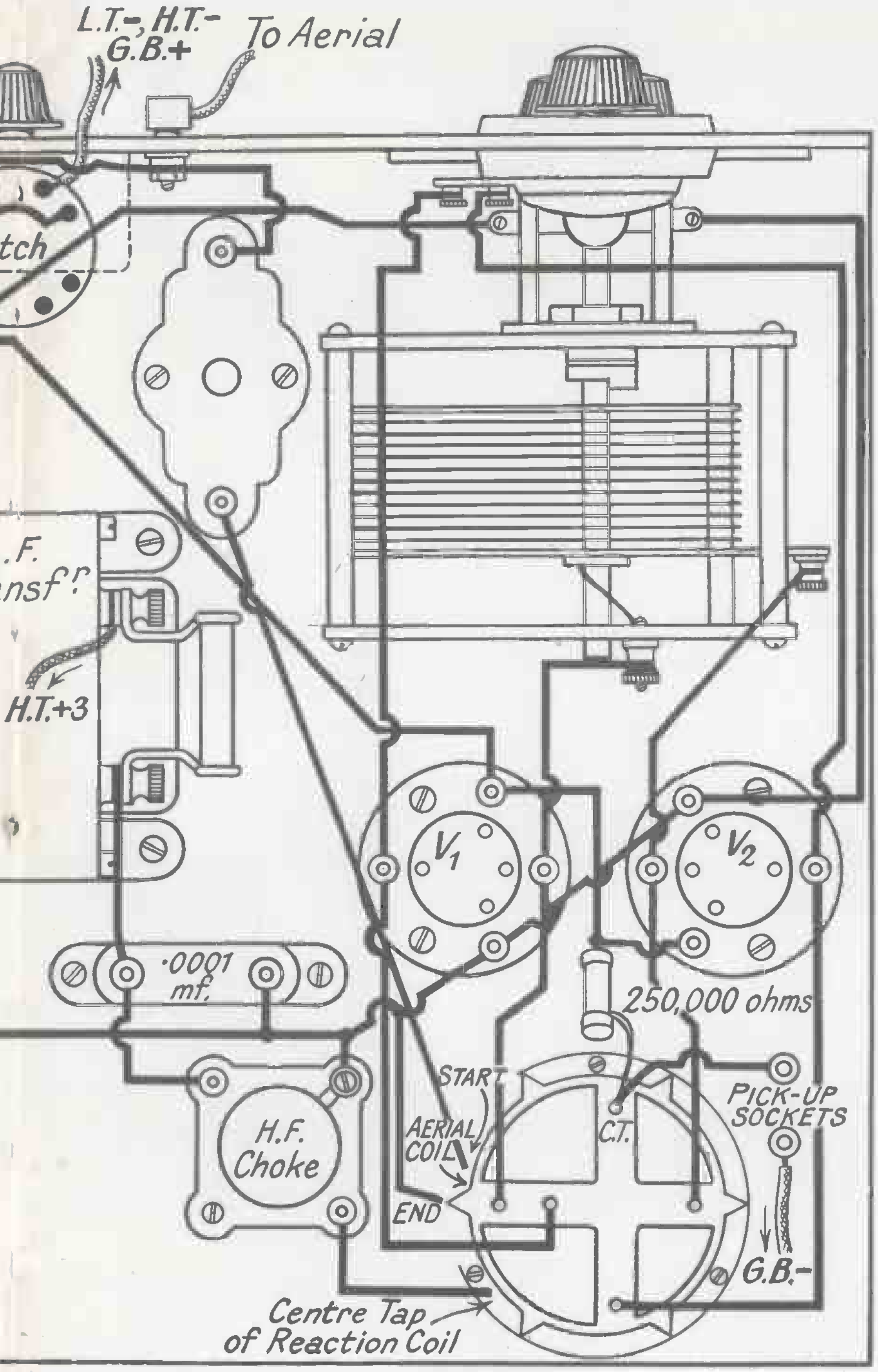


Fig. 7.—The Set
The whole of the wiring is here shown in place.



WIRED COMPLETE.
The switch terminals are indicated by dots.

dency to self-oscillation; or, better still, use a sensitive milliammeter to detect any sign of distortion.

Balancing the Detectors

The signal strength from the pair of valves should be a little better than that fiom a single valve, and remarkably clear and pure, but should any sounds be heard other than that of the transmission, and in particular a noise somewhat like a sewing machine at work, this means that the valves are out of balance and working incorrectly.

First try reversing the valves in the valve holders; this may cure the trouble, but if not the trouble will almost certainly be due to stray capacities. To determine this—in the absence of elaborate test equipment—add a small variable condenser to one side of the circuit and note results.

Dealing with Stray Capacities

Vary the value of the added

capacity; it may cure the trouble. If so, leave the condenser in the circuit, but test on several wavelengths to get the best average results. If no great improvement is obtained, try the same experiment on the other side of the circuit. Provided the condenser is of suitable capacity, the trouble should almost certainly vanish.

Should it not do so, then give attention to the reaction circuit. If possible, try a different resistance—one with no appreciable self-capacity and of negligible inductance is highly desirable.

Finally, test each individual wire by placing a small metal plate, connected by an insulated wire to earth, near each wire in turn. When the culprit is found it can be cured by making a few turns of insulated wire around it and connecting this wire to earth, or by shielding the wire and earthing the shield.

Superb Quality

Constructors should not think that the making of this set is one of insuperable difficulty; it is not. In most cases it will give superb quality straight away, but these simple tests and cures are mentioned here, so that should any trouble arise it can be dealt with effectively.

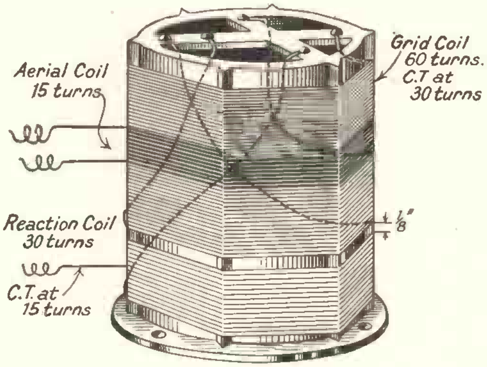


Fig. 8.—DETAILS OF COIL.
The proper arrangement and number of turns of wire are shown here.

Completing the Wiring

Having obtained satisfaction from the detector, remove the temporary wiring and complete the wiring of the set by making the various connections to the components, as shown clearly in Fig. 7 and in Fig. 11, illustrating the set wired up, but without the battery cords. The battery cords should be connected as follows:—

Red to L.T.+ on battery and to filament terminal of V3.

Blue to L.T.— on battery and to G.B.+ and to switch, the " Wanderfuse " to H.T.— on battery, and the free end to switch.

White to H.T.+ 1, 136 volts on battery and to centre tap of choke.

Yellow to H.T.+ 2, 134½ volts on battery and to screening grids.

Brown to H.T.+ 3, 120 volts and to H.T.+ on L.F. transformer.

Black to G.B.— 4½ volts on battery and 250,000-ohm resistance.

Black and white to G.B.— 1½ volts and to pick-up socket.

Balancing the L.F. Amplifier

Check all the wiring, then connect up the batteries, connect the loud speaker, and also connect the set to aerial and earth.

Note that the 16½-volt G.B. battery is used in series with the H.T. battery to increase the H.T. + voltage and provide 1½-volt steps for adjustment of screen voltage. The H.T. + terminal is connected to G.B. — in this case.

Switch off, then put the valves in position, switch on and tune in the local station. Perfect reception and good quality should at once be obtained, but it can be improved by balancing the pentode valves.

Remember always to switch off the set, by breaking the L.T. circuit, before making any voltage adjustments of any kind. Failure to do this may damage the pentode valves—or probably ruin them.

To balance the pentode valves remove one pentode, connect a milliammeter in the H.T.+ lead to centre tap of choke, switch on, but tune out the local station. Adjust the bias of the valve until a reading of about 1½ m.a. is obtained, switching off each time before changing the bias voltage.

Next adjust the screen-grid voltage to give about 2½ milliampere reading; note its value. Then repeat the performance with the second valve, but this time varying the screen-grid voltage only until the milliampere reading corresponds with that of the first valve, probably both will require the same voltage.

Replace the valves and again try the set ; a marked improvement will result. For maximum power work the set at $4\frac{1}{2}$ volts grid bias, $134\frac{1}{2}$ volts on screen grids and 136 volts on anodes. Under these conditions total current consumption will average only 8 m.a.

By-pass Condenser

In the circuit diagram a ·005-mfd. condenser is shown shunted across the L.S. terminals. This value is correct for the M3T "Ferranti" speaker, but in some cases better tone may result from a change in value, but a tone corrector circuit is not needed because the detectors deal faithfully with every subtle inflection of the modulated signal.

Fitting to Cabinet

The set is adaptable to most of the high-grade cabinets on the market. When making choice select one with ample space for the loud speakers and for a gramophone attachment, if this is desired.

If a console type of cabinet is used, the set and speakers should be arranged as shown in Fig. 14, while, if a pedestal type is preferred, the arrangement in Fig. 15 can be adopted.

The "Univolt" standard unit converts this set to a radio-gramophone of superb quality and great power, but when this is required connections between the unit and the set should be made as shown in Fig. 12, one lead from the "Univolt" going to G.B.— $1\frac{1}{2}$ volts, the other to a terminal on the baseboard.

A flexible wire with plug is connected to this terminal, and whenever the gramophone is required the plug is inserted in a small socket connected to the centre tap of the grid coil and the aerial disconnected.

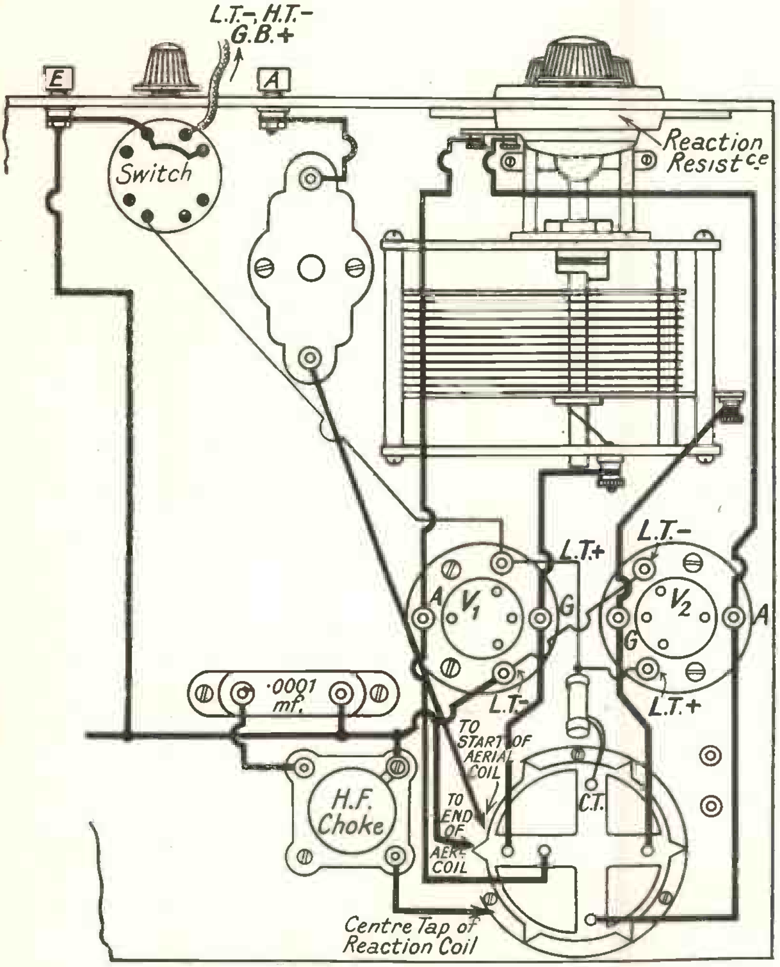


Fig. 9.—THE DETECTOR CIRCUIT WIRING.
Showing the wires to add after completing the filament wiring.

A switch should not be used, as it will probably introduce unbalanced capacity into the detector circuit when receiving radio transmissions.

Completing the Receiver

Having obtained the cabinet and fitted the batteries into their appointed places and fitted the "Univolt" attachment and loud speakers, proceed to build up the baffle, using the special Slagbestos and materials supplied with the box baffle kit.

The final result is a receiver having magnificent tonal qualities, and one that is a real pleasure to listen to for lengthy periods.

Special Loud Speaker

If one of the new Celestion "Reetone" S.29 dual speakers are used, the output choke and two 2 mfd. and the ·005 mfd. condensers should be omitted and the speaker connected directly into the circuit. It is designed to be worked in this way, and on test gave irreproachable reproduction, both of radio and gramophone records.

Connect the H.T. + direct to the centre terminal of the transformer on the S.29 speaker, instead of taking it to the choke; connect a wire from each of the outer terminals on the speaker transformer to the anodes of the pentode valves.

Normally, the high-note control plugs on the speaker should be connected to the black and yellow sockets, but for maximum bass response the plugs can be inserted in the black and green sockets. Switch off before changing the plugs to avoid voltage surges through the pentode valves.

The S.29 speaker when connected correctly and used with this receiver gives a remarkably liquid and effortless purity of reproduction that is amazingly realistic.

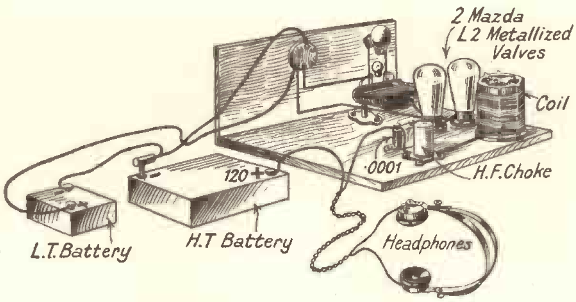


Fig. 10.—Testing Detector Circuit.

This pictorial diagram shows how to connect temporary headphones and batteries for testing detector circuit. Only the components concerned are indicated. The others are omitted for the sake of clarity.

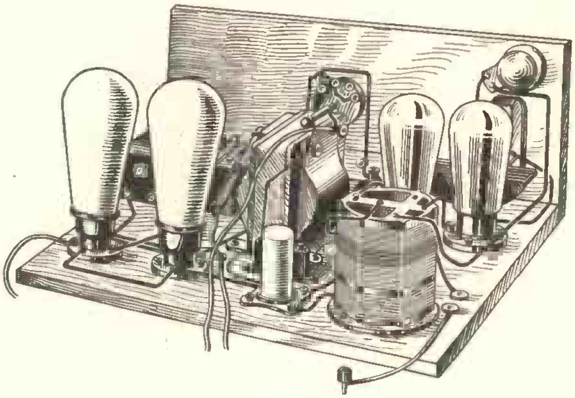


Fig. 11.—The Set Wired Up Complete.

The battery cords are not shown connected to the batteries in this illustration.

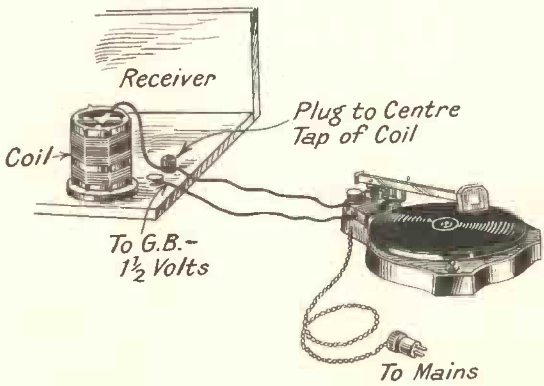


Fig. 12.—Connections to "Univolt" Unit.

This diagrammatic view shows how to connect a "Univolt" unit for playing gramophone records.

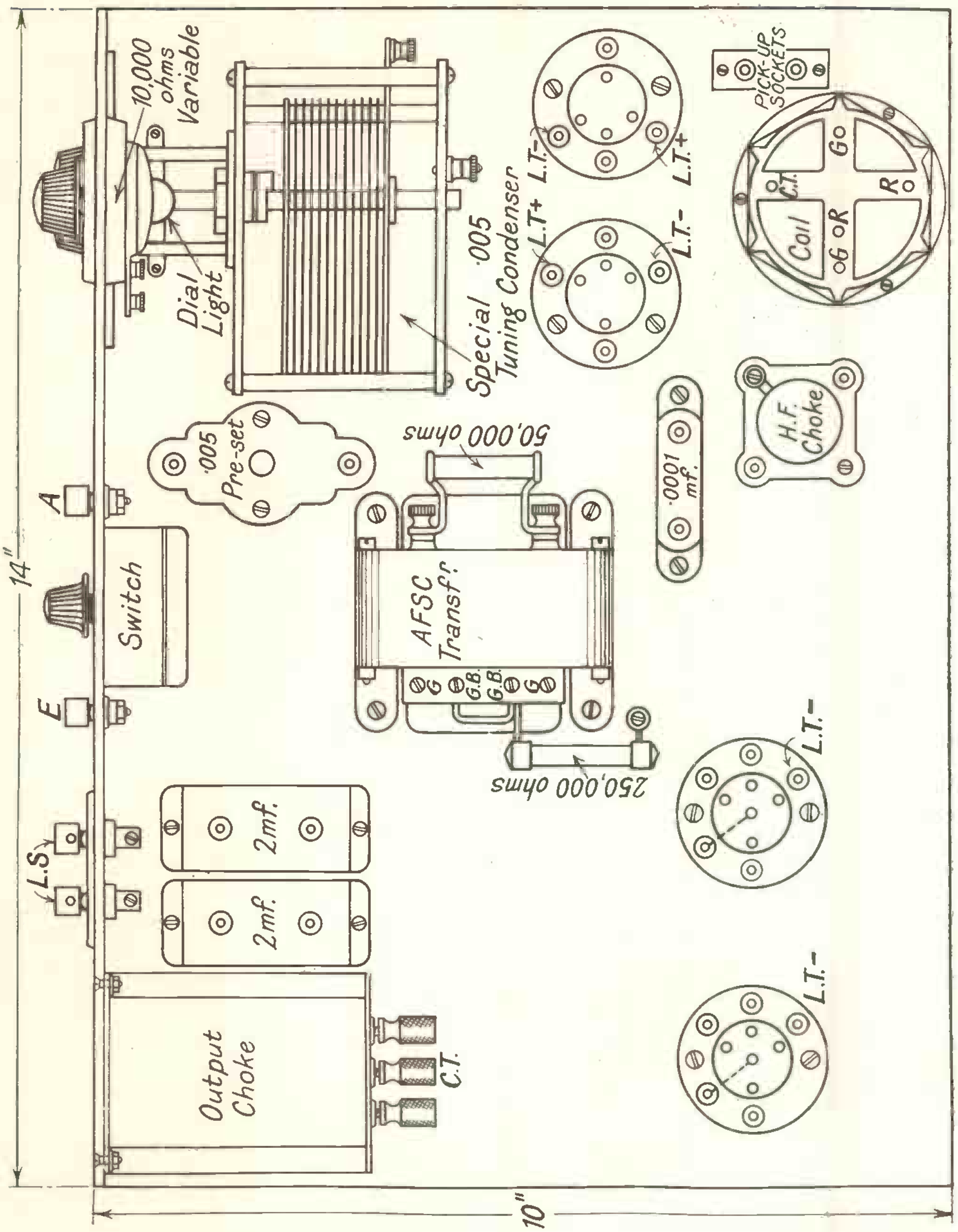


Fig. 13.—Layout of Components on the Baseboard.

Correct layout and wiring are very important for this set, as unless it is properly done the results will be very poor. The approximate positions of the components shown in this illustration should be very closely followed.

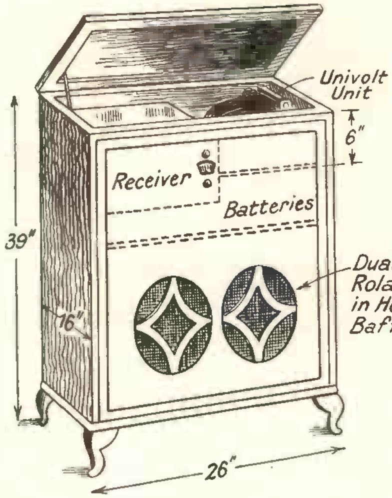


Fig. 14.—CONSOLE SET.

The "Double Push-Pull" with Univolt unit and dual speakers makes an ideal set for perfect reproduction from the local station or gramophone records. In order to bring the tuning control approximately in the centre of the cabinet, the wiring of the set would in this instance be carried out in the reverse way.

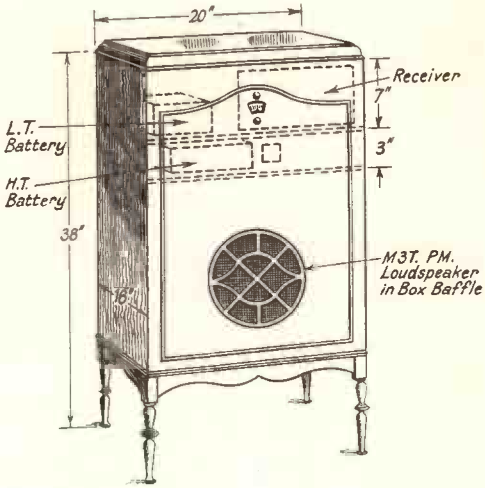


Fig. 15.—ARRANGEMENT OF PEDESTAL SET.

Sectional diagram showing how to fit the "Double Push-Pull" into a pedestal cabinet. No difficulty should be experienced in arranging the components as shown here.

Final Notes

Results, when everything is well adjusted more than justify the trouble of getting everything perfect.

The importance of following the arrangement specified in this article has been specially stressed so that constructors may know the reasons for the specified lay-out and the paramount importance of correct wiring.

A Note on the L.F. Amplification

The L.F. amplifier spould be carefully wired and well balanced, but it does not call for such meticulous care as the remainder of the circuit, because practically all the necessary balancing can be done by adjustment of grid bias and screening voltage, as already explained.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XX—UNITS AND MEASUREMENTS

THERE exists a great deal of confusion in the mind of the average experimenter as regards the units used to measure various electrical and magnetic quantities. I have come across " practical men " who were talking about a 0·001 condenser without qualifying the figures by any sort of unit and who were entirely innocent of any sort of understanding what a farad or a microfarad meant.

This sort of thing may be quite all right while one is pottering or merely copying blue prints, but if there is any attempt of designing a circuit intelligently the lack of knowledge of units and their origin is sure to prove a very heavy handicap.

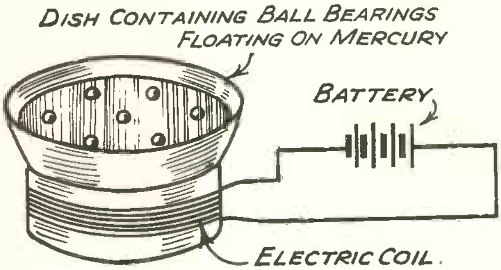


Fig. 1.—THIS DIAGRAM ILLUSTRATES AN INTERESTING THEORY OF THE CONSTRUCTION OF MATTER SUGGESTED BY SIR J. J. THOMSON.

This shows seven ball bearings floated on mercury contained in a dish standing over an electric coil carrying a current. They will arrange themselves in definite groups according to the number present.

It is usual for a beginner to be satisfied with this sort of thing. " One volt is a pressure which will drive a current of 1 ampere through a resistance of 1 ohm. One ampere is the current which will flow through a resistance of 1 ohm at a pressure of 1 volt. And 1 ohm is a resistance which with a pressure of 1 volt will cause a current of 1 ampere to flow." Such a series of " definitions " is about as valuable as the statement that one lives opposite a church. " And where is the church ? " " Oh, it is opposite my house."

The idea of this article is to clear up any doubts that may exist in the mind of the reader regarding fundamental units.

Three Fundamental Quantities

Now, in measuring, in the first instance we are concerned with three fundamental quantities : *length, mass* and *time*. The units measuring these three fundamentals are *absolute units*.

The French System

There are two systems in existence : Firstly, the French system, which uses the *centimetre* for measuring length, the *gramme* for measuring mass, and the *second* for measuring time. These units, centimetre, gramme, second, gave the abbreviated name of C.G.S. to this system.

The English System

Secondly, there is the English system, which uses the *foot* for measuring length, the *pound* for measuring mass, and the *second* for measuring time. The foot, pound, second gave the abbreviated name of F.P.S. to this system.

The Unit of Length

Now, let us see how these units were derived in the first place. 1/10,000,000 part of the portion of the meridian between the north pole and the equator passing through Paris has been chosen as unit of length and called a *metre*. This metre has been divided into 100 equal parts, and each hundredth of a metre has been called a *centimetre* (centi means a hundredth). Similarly, a tenth of a metre is called a *decimetre*, and a thousandth of a metre is called a *millimetre*. For this reason the French system is often referred to as the *metric system*.

Definition of a Centimetre

The official definition of a centimetre is as follows :—

One centimetre is one-hundredth of the distance between two marks of a platinum bar at the standard temperature kept at the Archives de Paris.

You see, the French made a standard platinum bar of 1 metre length and divided it into a hundred equal parts, so that each division represents a centimetre. This bar is kept at a standard temperature, as with variation of temperature the length of a metal bar varies.

Everybody understands clearly what length is, and, provided that we are given a suitable unit for measuring length, this measurement does not represent any difficulty.

The Unit of Mass

When we come to units for measuring mass the thing is not so simple, as there are many who do not understand what is meant by the word *mass*.

How Volume is Measured

In order to make this clear, let us see how with the help of units of length we arrive at the idea of *volume*. If we take a square which has a side two units long (Fig. 2) its area is *four* square units, as you can see from the sketch. Thus, we measure areas in square units of length, or, in other words, we measure areas with help of a square of a unit side. Similarly, it is possible to carry out measurements in three dimensions and compare a given volume with the volume of a cube having a unit side (all the sides of a square or a cube are equal in length) (Fig. 2). As you can see from Fig. 6, the volume of a cube having a side of two units is equal to the volume of eight cubes having one unit side. We, therefore, measure volume in cubic units.

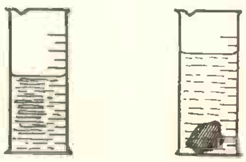


Fig. 3.—MEASUREMENT OF VOLUME.

Volume can be found by measuring the amount of rise of water or other liquid in a measuring cylinder.

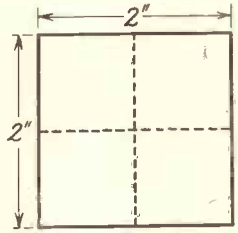


Fig. 2.—DIAGRAM TO ILLUSTRATE THE IDEA OF VOLUME.

What is Meant by Density

The next idea to master is that of *density*. It is clear that in a given volume we may have a different number of molecules of a certain substance. Thus, in a tank having a volume of 1 cubic foot we may have steam, we may have water, or we may have ice. In each case the density with which molecules are packed within the given volume is different.

Mass is the Product of Volume and Density

The amount of matter packed within a given volume thus depends upon the density of packing. This amount of matter is called the *mass* of matter, and it is clear that mass is merely the product of volume and density. Thus : Mass = Volume × Density ; also Density = $\frac{\text{Mass}}{\text{Volume}}$ and Volume = $\frac{\text{Mass}}{\text{Density}}$.

How the Attraction of Gravity is used to Compare Different Masses

In comparing different masses of matter we can utilise the attraction of gravity and see how these different masses are attracted to the centre of the earth, by weighing them. A balance is used for this purpose, and an unknown mass is balanced against a known or standard mass. In doing this we compare the force with which different masses are attracted to the earth's centre. If a given mass of matter is thus weighed with the help of a balance and standard

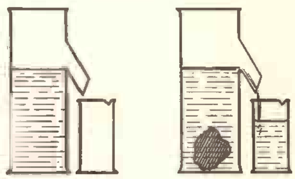


Fig. 4.—MEASUREMENT OF VOLUME OF IRREGULAR BODIES.

In a displacement vessel the body displaces liquid, the volume of which can easily be found.

weights, it will be found that the gravitational attraction is not the same at all points of the earth's surface. For this reason, if we are to give a definition of a unit mass, we must specify the portion of the globe to which it applies. The attraction to the centre of the earth is greater at the poles than at the equator, the reason for this difference being due to the fact that as we are getting nearer and nearer the equator the centrifugal force due to rotation of the earth around its own axis comes into play and counteracts to some extent the gravitational pull.

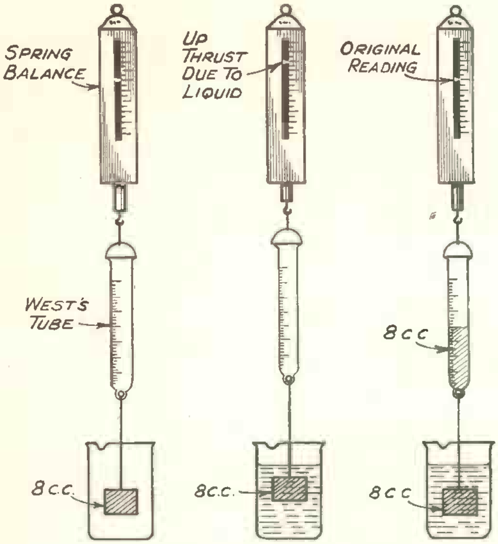


Fig. 5.—ARCHIMEDES PRINCIPLE.

A very important method of finding the volume of a body and its specific gravity.

Factors which Determine the Weight of a Body

It is clear therefore that the weight of a body depends upon its mass and it also depends upon the gravitational pull which varies from place to place. Thus, if we call the gravitational pull g, which is equivalent to linear acceleration of 32·2 feet per second per second, in London, and is therefore a constant for a given locality, we can say that:—

$$\text{Weight} = \text{mass} \times g.$$

From this follows that

$$\text{Mass} = \frac{\text{Weight}}{g}, \text{ and that}$$

$$g = \frac{\text{Weight}}{\text{Mass}}.$$

Difference Between Mass and Weight

It should be clear by now that the terms mass and weight are not identical terms. Mass of a body is the quantity of matter it contains and the weight of a body is the force of attraction which the earth exercises upon it. In the C.G.S. system *the unit of mass is the gramme, which is one-thousandth part of the mass of a piece of platinum kept at the Archives de Paris.* In the English system we have the *pound weight,* which is the unit of force of attraction which the earth exerts upon a certain standard piece of platinum. The unit of mass is taken as the mass of matter which weighs g pounds.

In practice there is constant confusion of the terms mass and weight, but since weight is mass $\times\, g$ and when we are comparing the weights of two bodies, and both are their respective masses multiplied by g, *i.e.,* the same quantity, the masses are proportional to weights, and therefore the comparison holds good.

The Unit of Time

The fundamental unit of time in both systems is the *mean solar second,* 86,400 of such mean solar seconds make a solar day.

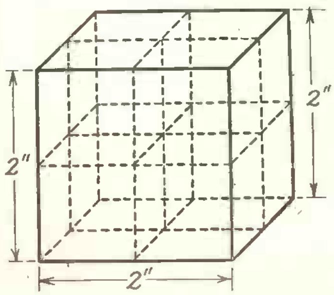


Fig. 6.—DIAGRAM SHOWING THAT THE VOLUME OF A CUBE HAVING A SIDE OF TWO UNITS IS EQUAL TO THE VOLUME OF EIGHT CUBES HAVING ONE UNIT SIDE.

Symbols for each Fundamental Unit

Let us give each fundamental unit a symbol, as follows:—

Unit of length	.	L
Unit of mass	.	M
Unit of time	.	T

Now we can derive other units from these three.

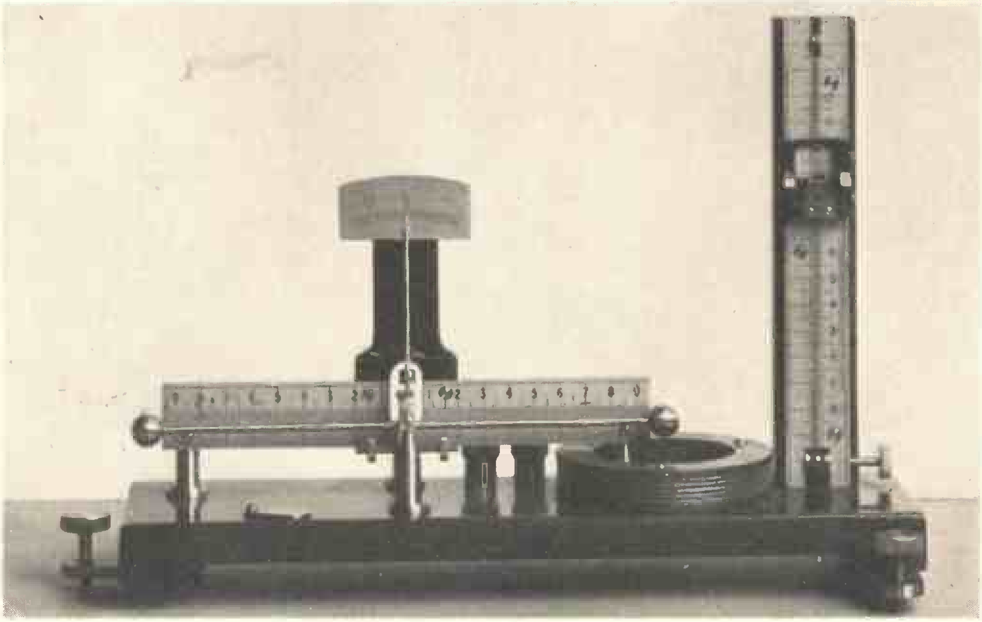


Fig. 7.—THE HIBBERT MAGNETIC BALANCE.

This apparatus has been designed to demonstrate how the attraction between two magnetic poles varies according to the distances between them. Here we see a long bar magnet pivoted at the centre with spherical pole pieces at each end. This magnet is held in a clamp, and it is balanced on fine steel points. Now turn to Fig. 8.

In the first place, we already know that we measure areas in square units of length. Therefore AREA $= L^2$ } L being a certain
Also VOLUME $= L^3$ } unit of length.

How to Find the Velocity of a Body

Now, *velocity* is the rate of change of distance, *i.e.*, if we want to find the velocity of a body we have to divide the distance covered by that body by the time taken to do so. Thus:

$$\text{Velocity} = \frac{\text{Distance}}{\text{Time}} = \frac{L}{T}.$$

How to Find the Acceleration of a Body

Acceleration is the rate of change of velocity. In order to find the acceleration of a body we have to divide its velocity by time. Thus :—

$$\text{Acceleration} = \frac{\text{Velocity}}{\text{Time}} \text{ or } \frac{\text{Velocity}}{T}, \text{ but}$$

since velocity is $\frac{L}{T}$ acceleration is $\frac{L}{T} : T$ or $\frac{L}{T^2}$. Therefore: Acceleration $= \frac{L}{T^2}$.

Force is a product of mass and acceleration. Therefore force $= \frac{ML}{T^2}$.

Density is mass ~~multiplied~~ divided by volume, and volume is represented as L^3, therefore

$$\text{Density} = ML^{-3}.$$

Now, let us collect all these ideas :—

Length	$= L.$
Area	$= L^2.$
Volume	$= L^3.$
Mass	$= M.$
Weight	$= Mg.$
Density	$= ML^{-3}.$
Velocity	$= \frac{L}{T}.$
Acceleration	$= \frac{L}{T^2}.$
Force	$= \frac{ML}{T^2}.$

From these symbolical expressions you can see at a glance how a certain item is made up. By looking at the last expression we see that force is due to mass, length

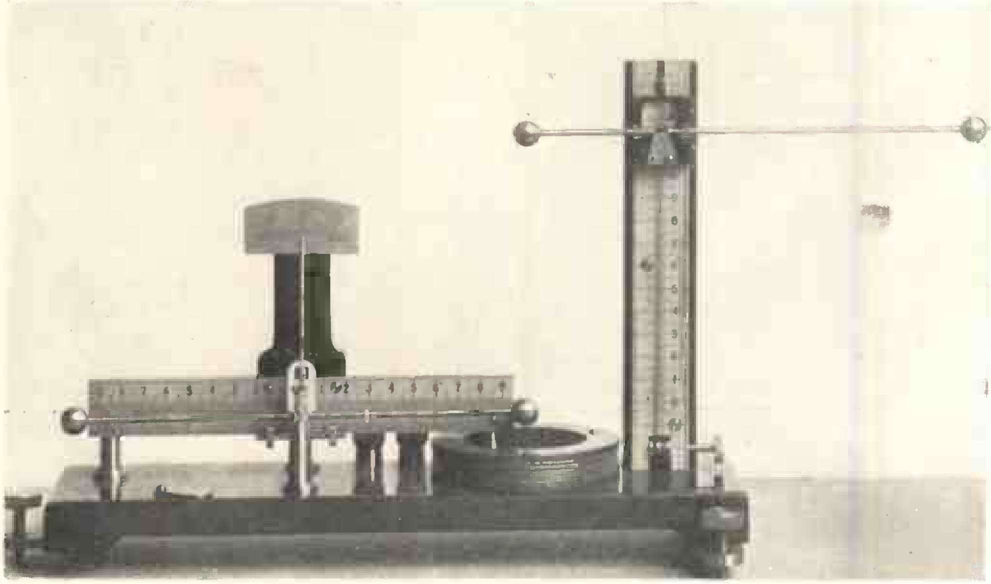


Fig. 8.—THE HIBBERT MAGNETIC BALANCE.

Here we see a similar bar magnet has been arranged with its pole 12 inches above the horizontal magnet. The upward pull has been counterbalanced by a small sliding weight which can be seen on the right-hand arm of the horizontal magnet.

and the square of the time. In analysing it into acceleration and mass we arrive at its definition.

The Dyne

In the C.G.S. system the unit of force is the dyne. *One dyne is a force which*

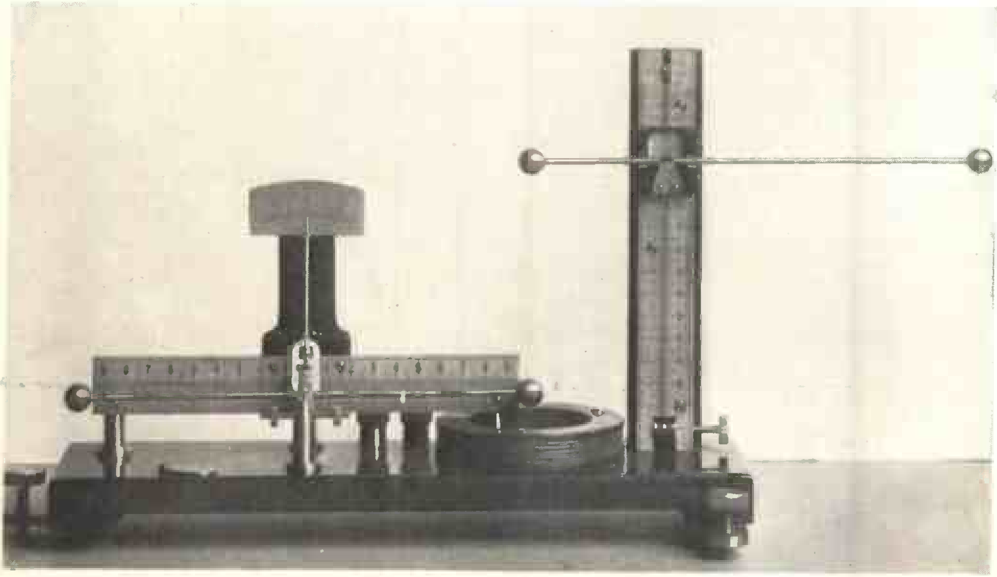


Fig. 9.—THE HIBBERT MAGNETIC BALANCE.

In this picture the upper magnet has been moved down 2 inches. The magnetic pull between the poles is now stronger, and the sliding weight on the horizontal magnet has had to be moved out to maintain equilibrium.

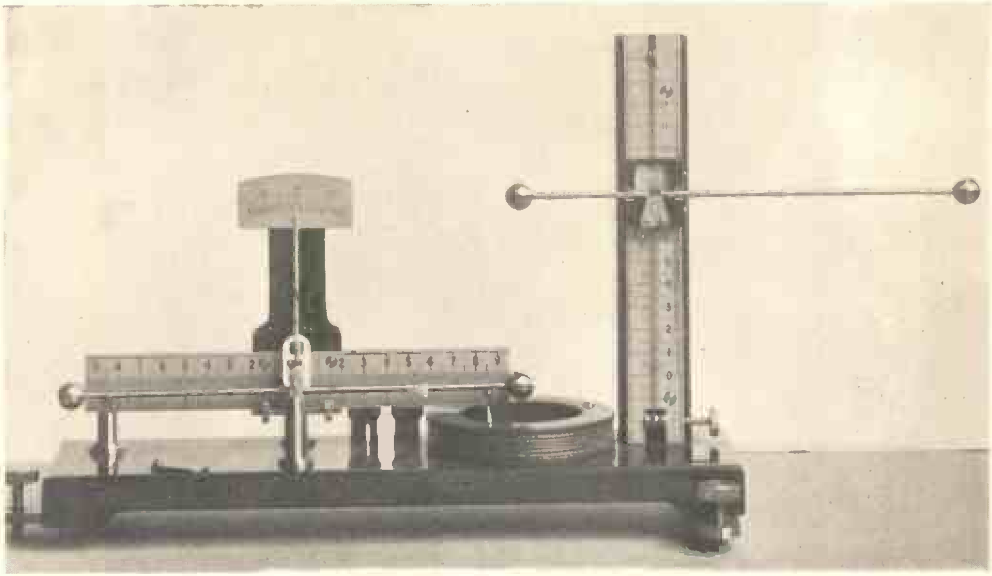


Fig. 10.—THE HIBBERT MAGNETIC BALANCE.

The distance between the poles is now only 8 inches. Note the new position for the sliding weight which has been placed so that it exactly balances a new magnetic force between the poles.

acting on a mass of 1 gramme for one second will communicate to it a velocity of 1 centimetre per second. Or it can be put this way: one dyne is a force which will give a mass of 1 gramme an acceleration of 1 centimetre per second per second.

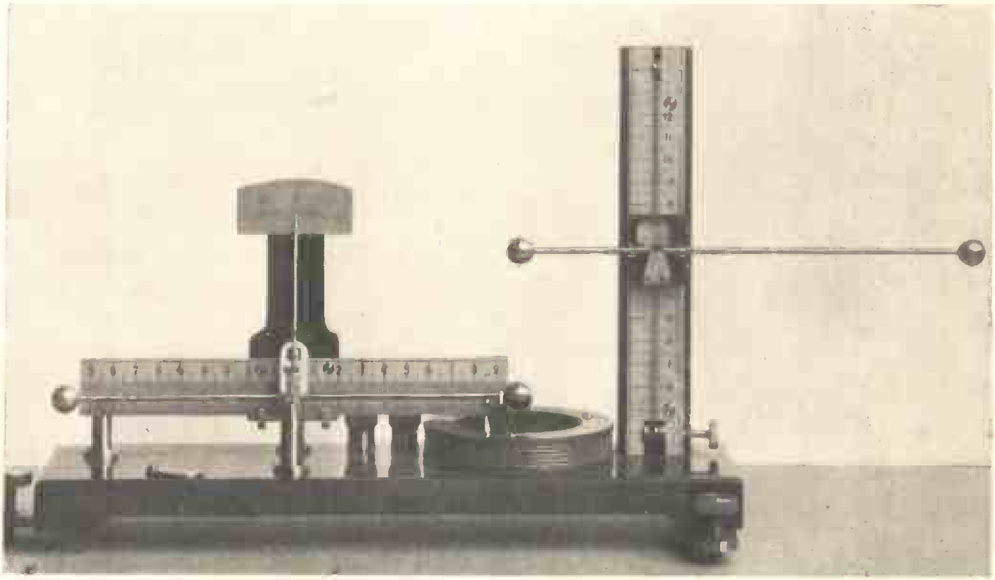


Fig. 11.—THE HIBBERT MAGNETIC BALANCE.

The two poles have now been brought to within about 6 inches of each other, and it will be noticed that the sliding weight has been placed at the extreme end of the scale in order to balance the stronger pull exerted. This is just one example of the ingenious methods designed by scientific men to investigate Nature's laws. The apparatus shown in these photographs is by Messrs. Griffin and Tatlock Ltd.

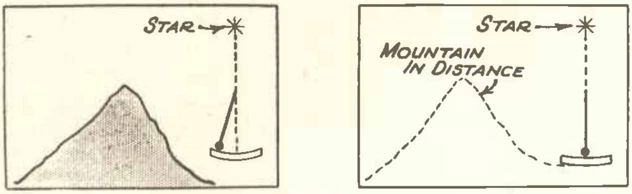


Fig. 12.—MEASURING MASS OF EARTH DIRECTLY.

This illustrates the method employed by Bourguer in Peru, 1740, to measure the mass of the earth. The method consists in finding out the attraction of a mountain on a heavy pendulum bob and from this calculating the mass of the mountain. One reading is taken south of the mountain and another due east. The parallel rays of light from a distant star are used as reference lines.

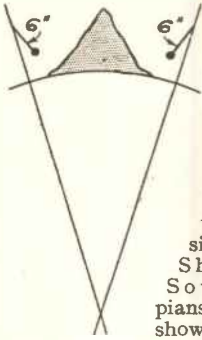


Fig. 13.—MEASURING MASS OF EARTH—MASKELYNE'S EXPERIMENT.

Readings taken at both sides of Mt. Shiehallein, South Grampians, Perthshire, showing deflections of 6 seconds out of the vertical.

Work—The Product of Force and Distance

The product of force and distance is called *work*. If you move five pounds over a distance of 100 feet you have done an equivalent of 500 foot-pounds of work. And the *foot-pound* is the English unit of work. On the C.G.S. system the unit of work is the *erg*.

One erg is the work done by a force of one dyne over a distance of 1 *centimetre*. In symbols: work = force × distance, and therefore:

$$\text{WORK} = \frac{ML}{T^2} \times L \text{ or } \frac{ML^2}{T^2}.$$

Power is the rate of doing work. Therefore power $= \frac{\text{work}}{\text{time}}$, and expressed in our symbols it is:

$$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{\text{work}}{T} \text{ or } \frac{ML^2}{T^3}.$$

Mechanical Unit of Power

The mechanical unit of power is the *horse power*, which is equivalent to 33,000 foot-pounds of work per minute, or 550 foot-pounds per second.

Before we start discussing electrical units, let us fix the relation between the C.G.S. and the F.P.S. units.

1 metre = 3·28089917 feet.
1 kilometre (1,000 metres) = 0·6213824 mile.
1 gramme = 0·0352739 ounce.
1 kilogramme (1,000 grammes) = 2·20462125 pounds.

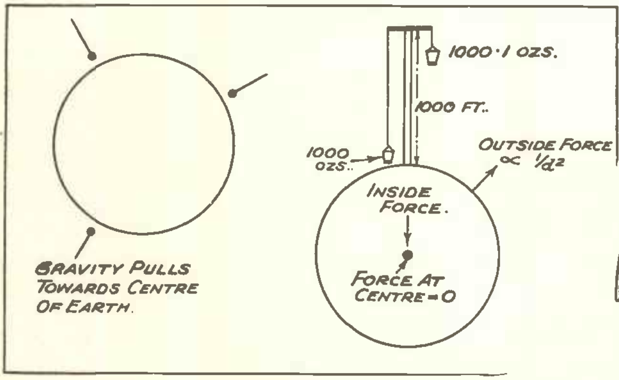


Fig. 14.—WHAT DOES PULL OF GRAVITY DEPEND ON?

Showing how the force of gravity depends only on the masses and distance between the bodies concerned. A weight of 1,000 ounces at the surface of the earth would balance a weight greater than itself situated 1,000 feet from the surface, showing the dependence of the force of gravity on the distance between the two bodies, *i.e.*, the weight and the earth.

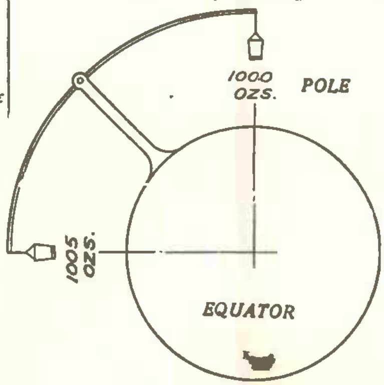


Fig. 15.—WEIGHT OF OBJECTS ALTERS AT DIFFERENT PARTS OF THE GLOBE.

A gallon of water weighing about 1,000 ounces at the North Pole would require 1,005 of the same ounces to balance it at the equator.

The French equivalent of power is *force de cheval.*

1 *force de cheval* = 0·986337 horse power.

Three Systems of Electrical Measurements

In electrical measurements there are three systems in existence. One is the *electro-magnetic* system of units, the second is the *electrostatic* system of units, and the third is the *practical system* of units.

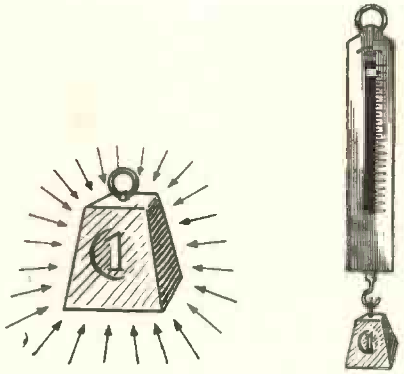


Fig. 16.—Distinction between Mass and Weight.

The mass of a body is the quantity of matter is contains and the weight of a body is the force which the earth exercises upon it. The mass remains constant, but the weight depends on where the body is, *e.g.*, at the Equator it is lighter than near the Poles.

THE ELECTRO-MAGNETIC SYSTEM

From the definitions that follow you will see how use is made of the fundamental units. The electro-magnetic system of units is based upon the attraction of two magnetic poles. If we have two magnetic poles, one of strength m and the other of some different strength m_1, we can find experimentally that the force of attraction between the two poles is equal to the product of their strength divided by the square of the distance between them, this means that force $= \frac{mm_1}{L^2}$.

If the two poles happen to be of equal strength m, then force $\frac{mm}{L^2} = \frac{m^2}{L^2}$. In this manner we have force $= \frac{m^2}{L^2}$, but we have a symbolic expression for force which is $\frac{ML}{T^2}$, so that we can put down $\frac{ML}{T^2} = \frac{m^2}{L^2}$, and therefore $m^2 = \frac{ML^3}{T^2}$, which means that $m = \sqrt{\frac{ML^3}{T^2}}$.

From this last equation it is clear that we have succeeded in expressing the strength of a magnetic pole in the terms of mass, length and time. Those of my readers who are not strong on mathematics need not worry about following the various equations, provided they see that there is a connection between the electrical units and the fundamental units.

Permeability

The attraction between two magnetic poles is affected by the medium through which this attraction takes place, and for this reason we have to introduce in the above formula a term μ, which denotes the *permeability* of the medium. Therefore the final expression of the strength of a magnet pole is $m = \sqrt{\frac{\mu ML^3}{T^2}}$.

If M, L and T are units, then m is a unit pole. The μ in the above equation is the index of our ignorance of the mechanism of magnetic attraction, as it is an extra term which cannot be expressed in fundamental units. The square root ($\sqrt{\ }$) is a further index of our ignorance of the exact nature of the phenomenon. If we knew exactly what is happening we should be able to express the above without μ and without the square root.

The Gauss

The unit of magnetic field is the *gauss*, which is a field of such strength that a unit pole situated in it experiences a force of 1 dyne.

Maxwells

Magnetic flux is measured in units called *maxwells*, one maxwell being one line of force.

The units of magnetic flux and magnetic field being established, since there is a definite relation between electric current and the magnetic field it produces, it is possible to calculate mathematically the relation between the current and the magnetic field and express this current in the terms of the magnetic field. Thus a whole system of electro-magnetic units is established which have a definite relation (as we shall see later) to all other units.

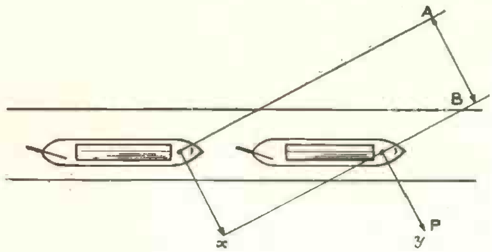


Fig. 17.—WORK IS MEASURED IN THE DIRECTION OF THE FORCE.

A horse pulling a barge is taken in this example. Distance travelled is from x to y, but the work done = force P × distance AB ft. lb.

THE ELECTRO-STATIC SYSTEM

Just as we have taken as a starting point in the electro-magnetic system of units the attraction between two poles, so we can in the electro-static system of units start with the attraction of two charges.

If we have two charges q and q_1, one positive and the other negative, placed near each other, there will be a force of attraction between the two charges and the law governing this attraction is the same as in the case of the magnetic poles, namely, force of attraction $= \frac{qq_1}{L^2}$.

If the two charges are equal in magnitude and each is q, this force becomes $\frac{q^2}{L^2}$.

Once more we have force

$$= \frac{ML}{T^2} = \frac{q^2}{L^2} \text{ or } q = \sqrt{\frac{ML^3}{T^2}}.$$

Once more the medium influences the attraction, and in order to take this into consideration we have to introduce a term k, which is the *dielectric constant* of the medium, so that our final equation is

$$q = \sqrt{\frac{kML^3}{T^2}}.$$

And once more the term k and the square root show our ignorance in the matter of the mechanism of electro-static attraction.

Since electrical current is the rate at which an electric charge passes along a conductor, we can work out all other units in terms of the electrical charge and thus produce an electro-static system of electrical units.

THE PRACTICAL SYSTEM

But the electro-magnetic system of units is not suitable in practice. The practical unit of current, namely, 1 ampere, is only one-tenth of the unit of current on the electro-magnetic system. The same objection applies to the electro-static units. It is for this reason that the practical electrical units have been introduced.

Let us survey them and see what their exact definitions are.

How the Proton and Electron could be Used for a System of Units

Up to the present the natural quantities represented by the electron and the proton have not been used for the formation of a system of units which could be derived, naturally, one from the other and thus form a single natural system of units. Thus the mass of the proton could be taken as the unit of mass (equal to $1{\cdot}63 \times 10^{-24}$ grammes).

Similarly, the electrical charge contained in an electron, or rather the quantity of electricity contained in an electron, forms a natural unit of quantity of electricity. This quantity of electricity expressed in practical units is $1{\cdot}59 \times 10^{-19}$ coulombs. Thus, 1 coulomb of electricity contains approximately 6,000,000,000,000,000,000 electrons.

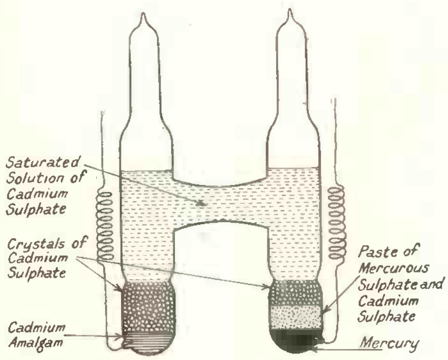


Fig. 18.—THE WESTERN NORMAL CADMIUM STANDARD CELL.

This, however, is only to show how convenient the electron is for the purpose of a system of units. *One ampere is a current of 1 coulomb per second passing a point of a conductor.* Thus an ampere can be expressed as 6×10^{18} electrons passing a point each second.

The Volt—The Unit of Electromotive Force

The unit of electromotive force is the *volt.* This is the practical unit used for measuring E.M.F., potential difference and potential.

In the electro-static system potential is defined as the work done in ergs in bringing a unit charge from infinity to the point, the potential of which is being measured. Difference of potential between two points is similarly defined as the amount of work done in ergs by carrying a unit charge from one point to another, and the E. M. F. across a circuit is defined as the work done in carrying a unit charge around the circuit.

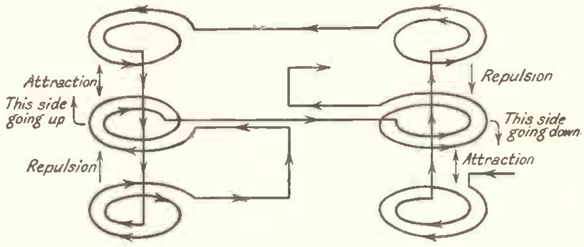


Fig. 19.—THE PRINCIPLE OF THE AMPERE BALANCE.

In practice, however, we take the volt to be as the approximate E.M.F. of a standard cell.

Practical units have two definitions: the international and the legal.

The *international volt* is $\frac{1}{1\cdot0183}$ of the E.M.F. of a standard Weston Cadmium cell at 20° Centigrade.

The *legal volt* is $\frac{1}{100}$th of the potential difference, which produces a certain deflection on a standard electro-static voltmeter kept at the Board of Trade.

The Ohm—The Unit of Resistance

A unit of resistance is the *ohm.* The *international ohm* is the resistance of a column of pure mercury, 106·3 centimetres long and having a cross-section of 1 square millimetre (this column should weigh 14·4521 grammes) at 0° Centigrade (the resistance of metals increases with temperature).

The *legal ohm* is the resistance at 16·4° Centigrade between the terminals of a *standard ohm* kept at the offices of the Board of Trade.

The Inverted Ohm

There is a unit called *mho* which is the inverted ohm, which serves for measuring the conductance of a circuit. The conductance of a circuit is the reverse or the reciprocal of resistance.

Thus, conductance $= \frac{1}{\text{resistance}}$. If the resistance of a circuit is 10 ohms its conductance is $\frac{1}{10}$ mhos.

The Ampere—The Unit of Current

The unit of current is the *ampere.* The *international ampere* is the current which deposits 1·118 milligrammes (a milligramme is a thousandth of a gramme) of silver per second when passed through a solution of silver nitrate.

The *legal ampere* is the current which gives a certain reading on a standard *ampere balance* kept at the offices of the Board of Trade.

The Ampere Balance

The last sentence suggests that somehow current is being weighed. The ampere balance is an interesting piece of apparatus, and is based on the principle that currents flowing in two neighbouring conductors in the same directions repel each other (*i.e.*, the conductors are being repelled), and when flowing in the opposite directions attract each other. For this reason, if conductors are arranged as shown in Fig. 19, the middle coils which are delicately balanced will be tilted, one side going down and the other side going up, and this tilt will depend upon the current strength flowing through the coils. If the tilted coils are now balanced by means of small weights, it is possible to find a relation between these restoring weights and the strength of the current causing the tilt. The ampere balance can thus be calibrated to read in amperes, each degree of tilt corresponding to some strength of current and therefore a definite amount of weights corresponding to some definite strength of current.

The Watt

Thus we have the definitions of the three quantities involved in Ohm's law. Electrical power is measured in units, called *watts*. One watt is the power developed in a circuit in which 1 ampere of current is flowing at a pressure of 1 volt. Therefore a watt is the product of 1 volt and 1 ampere. If the current is 10 amperes and the pressure is 100 volts, the power developed is 100×10 watts, or a 1,000 watts. A 1,000 watts is lumped into one unit, called the *kilowatt*. In alternating current circuits the power is the product of volts, amperes and the power factor.

The Coulomb

From the definition of the ampere follows the definition of the practical unit of *quantity of electricity*. This unit is the coulomb, and can be defined as the quantity of electricity represented by the flow of 1 ampere per second. From this we have the ampere hour, *i.e.*, the flow of 1 ampere for an hour, as a measure of capacity of an accumulator. A forty-ampere hour accumulator will deliver 1 ampere of current for forty hours or 40 amperes for an hour (I do not advise you to try the latter discharge). It will also deliver $\frac{1}{2}$ ampere for eighty hours, and so on.

The Joule

The unit of work is the joule, which is the work done in one second when a current of 1 ampere is maintained by an E.M.F. of 1 volt.

Thus 1 joule equals to 1 watt per second.

The commercial unit of electrical work done is the Board of Trade unit, also called 1 *kelvin*. This is the kilowatt-hour, *i.e.*, 1,000 watt-hours. The following relations should be noted :—

1 ampere hour	=	3,600 coulombs.
1 kilowatt	=	1·346 horse power.
1 kilowatt	=	1·36 *force de cheval*.

How the Capacity of a Condenser is Measured—Farads and Microfarads

The capacity of a condenser is measured in units, called *farads*. One farad is the capacity when a charge of 1 coulomb (1 ampere per second) raises the potential of the condenser by 1 volt. This unit is too large for use in wireless, and the usual unit is for this reason a millionth of a farad, called a *microfarad*. Sometimes it is necessary to use a still smaller unit and a millionth of a microfarad is used, which is then called a micro-microfarad.

Capacity is also measured in centimetres and in jars (a naval unit). The relation between these three units is as follows :—

1 farad = 9×10^{11} absolute units or centimetres.

1 farad = 9×10^{8} jars.

The Henry—The Unit of Inductance

The unit of inductance is a henry. A circuit has an inductance (self-inductance) of 1 henry when an E.M.F. of 1 volt is induced in it while the current is changing at the rate of 1 ampere per second.

Prefixes used with Electrical and other Units

The following prefixes are used with electrical and other units :—

Prefix.	Its Meaning.
Mega . .	A million
Kilo . .	A thousand
Deci . .	A tenth
Centi . .	A hundredth
Milli . .	A thousandth
Micro . .	A millionth

Thus a millivolt means a thousandth of a volt, a microampere means a millionth of an ampere, a megohm means a million ohms, etc.

The following table will sum up all the

units and show the relation between the electro-magnetic, electro-static and the practical units.

TABLE OF PRACTICAL UNITS

Item.	Name of Unit.	Equivalent in Electro-magnetic Units.	Equivalent in Electro-static Units.
Quantity .	Coulomb	10^{-1}	10^{-1}
Current .	Ampere	10^{-1}	10^{-1}
E.M.F. .	Volt	10^{8}	10^{8}
Resistance	Ohm	10^{9}	10^{9}
Capacity .	Farad	10^{-9}	10^{-9}
Inductance	Henry	10^{9}	*nil*

Note 10^{-1} means $\frac{1}{10}$th ; 10^{-9} means $\frac{1}{1,000,000,000}$th ; 10^{8} means 100,000,000.

QUESTIONS AND ANSWERS

What are the Three Fundamental Quantities Used in Measuring ?

Length.
Mass.
Time.

What System of Measurement is Used in Scientific Work ?

The centimetre—gramme—Second or C.G.S. system.

What is the Unit of Length in the Metric System ?

The unit of length is approximately 1/10,000,000 part of the portion of the meridian between the North Pole and the Equator passing through Paris, and is called a metre.

What is the Unit of Mass ?

The unit of mass is the gramme, which is one-thousandth part of the mass of a piece of platinum kept at the Archives de Paris.

What is the Unit of Time ?

The fundamental unit of time is the mean solar second, 86,400 of such mean solar seconds making a solar day.

What are the Symbols Generally Used to Denote these Units ?

Unit of length ... L
Unit of mass ... M
Unit of time ... T

What is a Dyne ?

One dyne is a force which acting on a mass of 1 gramme for one second will communicate to it a velocity of 1 centimetre per second.

What is Work ?

Work is the product of force and the distance through which it is exerted. The unit of work is the erg which is the work done by a force of 1 dyne over a distance of 1 centimetre.

What are the Three Systems of Electrical Measurements ?

(1) The electro-magnetic system of units.
(2) The electro-static system of units.
(3) The practical system of units.

State briefly the Principle on which the Electro-magnetic System of Units is Based.

The electro-magnetic system of units is based upon the attraction of two magnetic poles. If we have two magnetic poles, one of strength m and the other of some different strength m, we can find experimentally that the force of attraction between the two poles is equal to the product of their strength divided by the square of the distance between them.

State briefly the Principle on which the Electro-static System of Units is Based

The electro-static system of units is based on the attraction of two charges. If we have two charges of q and q_1, one positive and the other negative, placed near each other, there will be a force of attraction between the two charges, the law of attraction being the same as for two magnetic poles.

What is the Difference between the International Volt and the Legal Volt ?

The international volt is $\frac{1}{1 \cdot 0183}$ of the E.M.F. of a standard Weston cadmium cell at 20° centigrade. The legal volt is $\frac{1}{100}$th of the potential difference which produces a certain deflection on a standard electro-static voltmeter kept at the Board of Trade.

SERVICING

KOLSTER-BRANDES 6-VALVE SUPERHETERODYNE MODELS 285 AND 286; AND MODELS 320 AND 321

THE models to be described are simple to service, for apart from the accessibility of the various parts, the eliminator is an entirely separate unit which is bolted to the top of the chassis. The same chassis and loud speaker is fitted to the table and console model and the description of the controls will, therefore, apply to both.

Fig. 1.—Fitting an Unwired Plug to the Safety Sockets of the Kolster-Brandes Receiver Models 285 and 286.

The Tuning Controls and Back Connections

At the front are two knobs, the one on the left being connected by a cord drive to a triple-gang condenser centrally placed under the chassis. The second control is a double potentiometer for varying the strength of signals. One resistance controls the aerial input circuit and the second varies the input to the intermediate-frequency valve.

The Output Jacks

Medium and long-wave ranges are selected by moving the lever on the right side of the cabinet up or down respectively. On the opposite side is a bakelite mains "On-and-Off" switch. At the back of the chassis are two output jacks on the right with a gramophone jack more centrally placed. The two output jacks serve a rather unique and useful purpose, for by inserting a telephone plug connected to an external loud speaker in the end jack, only this loud speaker is in operation, while the other output jack utilises both loud speakers. This forms a rapid check on the internal loud speaker and its connections.

Mains Socket

In the centre is a standard 5-ampere mains socket which, with the plugs attached to the removable back of the cabinet, forms a safety device which effectively prevents electric shock when the cabinet is open. It must be remembered that a standard *unwired* plug must be fitted in these sockets if current is required for service tests after the back has been removed (see Fig. 1). A 6-socket short-wave panel is fitted also at the back of the

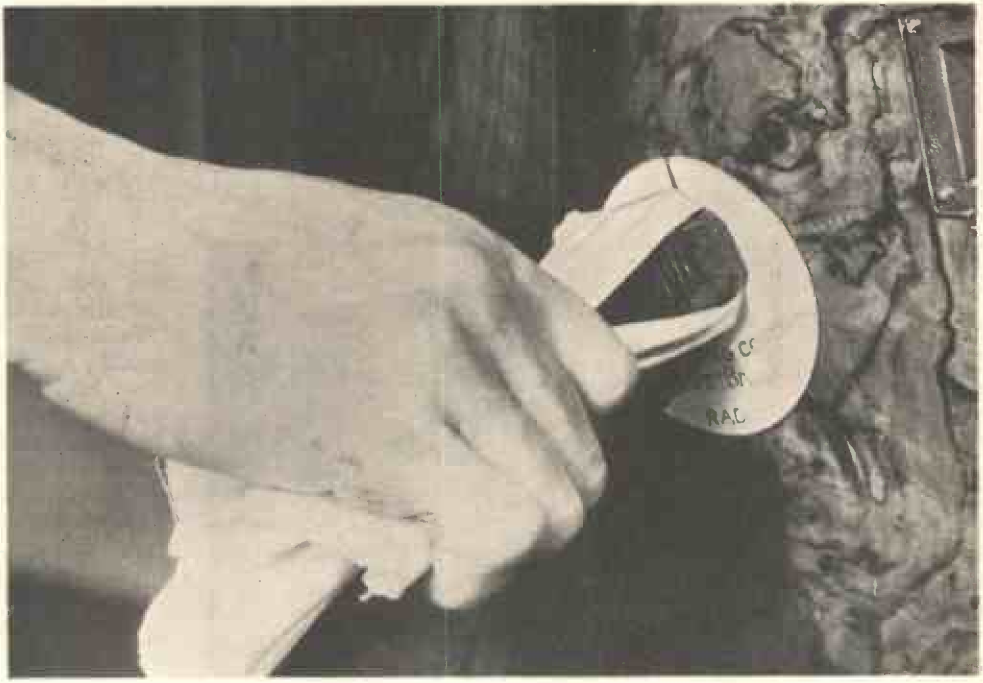


Fig. 2.—REMOVING THE CONTROL KNOBS WITH A DUSTER.

chassis, and above it is a small aerial and earth board.

The Arrangement of the Valves

It has been mentioned that the eliminator is a separate unit and it is electrically connected to the chassis by a terminal-strip and cable-form of different coloured wires. The opening in the eliminator case permits the insertion of a Philips 1807 full-wave rectifier valve. The valve table on page 1257 will enable voltage faults to be localised to a particular stage and gives the function of each valve from left to right as seen from the back of the chassis. The readings given were taken under full load, that is, with each valve working in its normal manner. Voltage and current readings are of necessity only approximate as slight variations in valves and in the supply voltage will tend to alter the results.

It is as well to check valve emission and to look for superficial faults before removing the chassis from the cabinet.

How to Check the Mains Supply and H.T. Voltages.

In the event of continual fuse blowing, inspect in the following order the mains plug or bayonet adaptor for stray wires causing a short circuit, and the mains cord up to the point of entry into the chassis. Then check the operation of the mains switch and the adjacent fuse-holder, which latter should carry at least an 800 m.a. fuse for 200-250 volt model or a 1,200 m.a. fuse for 100-120 volt type. The removal of the rectifier will show whether a short circuit in the H.T. supply is causing the fuses to blow.

Mains Transformer Tappings

The table on page 1251 gives the correct tapping points for A.C. mains of different voltages. In checking the correctness of these, make certain that no free strand of wire is shorting to adjacent tapping points or to the chassis. A faulty rectifier valve may blow the fuses by applying an excessive load to the mains transformer. An excessive load due to a H.T. short-

Fig. 3.—REMOVING THE LEVER OF THE WAVE-CHANGE SWITCH.

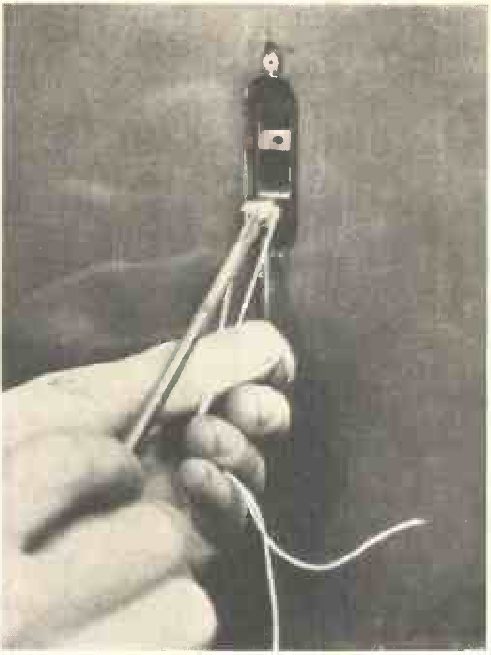


Fig. 4.—FITTING THE LEVER OF THE WAVE-CHANGE SWITCH.

circuit or the heater wires touching will be indicated by a loud mechanical hum in the transformer.

Checking the Valves

After running for fifteen minutes the valves should be appreciably warm. If the priming grid of the pentode becomes red-hot it is not receiving its correct H.T. voltage. The same symptom occurring in the inner grid indicates an open circuit in the grid-bias resistance to the cathode or lack of continuity through the auto-transformer from the grid socket to the chassis.

Table of Mains Transformer Voltage Tapping Terminals. Model K.B. 285. 100—150 *volts A.C., and Model* 286, 200—250 *volts A.C.*

Tapping.	Mains Voltage.
1	130–150
2	120–130
3	110–120
4	100–110
1	235–250
2	215–230
3	200–210

Tapping terminals read from left to right of the transformer.

How to Remove the Chassis from the Cabinet

(1) Pull off the two control knobs by slipping the edge of a duster under the knobs and pulling them steadily outwards (see Fig. 2).

(2) Unscrew wavechange switch lever and escutcheon plate (see Fig. 3).

(3) Remove two portions of back. Unsolder mains leads to mains switch and mains fuse, and remove leads to electrolytic condenser and output transformer, making a sketch of the latter for reconnecting.

(4) Unscrew loud speaker supporting bar and remove complete unit.

(5) Unscrew the four Parker Kalon

screws underneath the chassis board and the two brackets on the back of the chassis (if fitted).

The chassis may now be removed as a complete unit (see Fig. 5).

Connecting Up for Bench Test

The loud speaker unit may be arranged to stand on one edge of the baffle board and one end of the loud speaker support for convenience. Re-solder the condenser wires — red to the centre electrode and black to the condenser frame, and the leads to the output transformer.

Colour scheme of loud speaker leads.

YELLOW.—H.T. side of field coil.

BLUE.—Anode side of field coil, joined to one side of output transformer primary winding by short red lead.

GREEN.—Pentode anode lead joins second side of transformer primary winding.

BLACK.—There are two black leads, either of which is joined to the 68–1 ratio tapping of the secondary winding and the second to the common corner tag.

Fig. 5.—TAKING THE CHASSIS OUT OF THE CABINET.

There remains now to be connected only the two mains leads removed from one side of the mains switch and the fuse holder. It is a good plan to cover this join with insulating tape to avoid a short-circuit to the chassis when tipping it on to its side. Do not forget to use the temporary *unwired* safety plug in the sockets at the back of the chassis.

Stage by Stage Checking

It cannot be said that there are any particular faults associated with this instrument. If, however, one or more of the screened grid valve anode leads are allowed to short-circuit to the chassis for any length of time, the excess current is likely to damage and blacken the decoupling resistances of 3,000 and 30,000 ohms fitted in the red sleeving in the eliminator. A breakdown in the decoupling condensers or in other fixed condensers connected with the H.T. supply will also cause damage to these two resistances. A further but unlikely cause is the shorting of the intermediate-frequency trimmer in the anode of the I.F. valve.

Checking the Output Stage

The possibility of open-circuited priming or control grids of the pentode have been mentioned earlier and it is assumed that voltage, current and grid bias conditions have been tested with the table provided. Loud speaker faults, such as a burnt out speech coil or an open-circuit transformer secondary winding can be checked by plugging-in an extra speaker as has been described. Excessive hum in this stage may be traced to shorted turns in the field coil. This will raise all the normal voltages if a large number of turns are shorted. Probably the best check is found in the resistance value of the coil, which should not be lower than 1,900 ohms (see Fig. 6).

Shorted turns in the output transformer primary winding can be traced to a curious form of distorted output of signals occurring only when the volume control is turned well on. Weak signals may be due to the failure of the electrolytic condenser across the biassing resistance. In early models a condenser of ·005 mfd. capacity was fitted from pentode anode to chassis or across the output transformer primary winding. If a short occurs here there will be no signals.

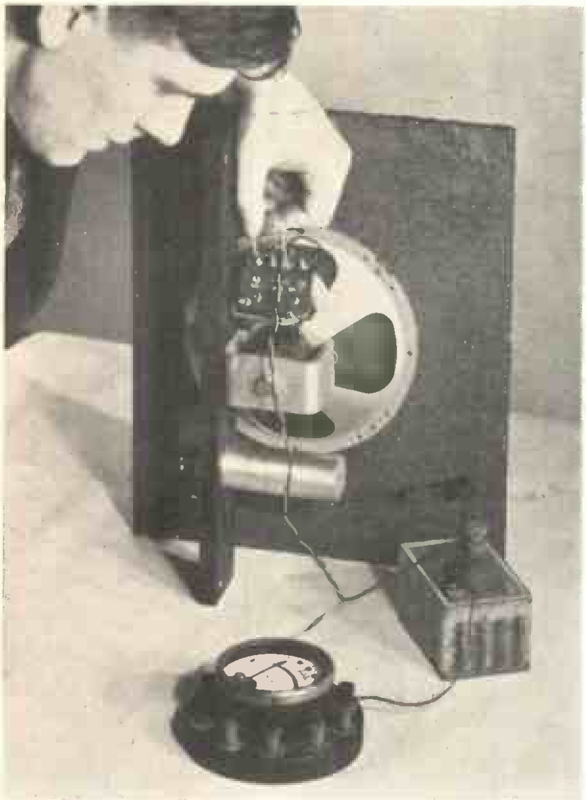


Fig. 6.—Checking the Resistance of the Loud Speaker Field Coil.

Checking the Second Detector

The only likely fault in the circuit is the failure of the anode to grid coupling condenser or open-circuited points in the pick-up jack. The latter is checked by touching the finger or the end of a metal screwdriver held in the hand, firstly on the grid side of the jack and then on the other side. If contact is made a loud squeal is set up in the loud speaker (see Fig. 7).

Checking the Oscillator

Breakdown faults occurring in condensers or coils are easily checked in this circuit, but more obscure are tuning faults which throw out of adjustment the wavelengths shown on the scale. Exceptionally high or low wavelength readings are traceable to the oscillator and may be due to bad contact of the wavelength switch connections, to shorted turns in the coil or to an open-circuited condenser. Switch blades may be bent further inwards, cleaned with a piece of fine rag (see Fig. 8), and finally smeared with a little vaseline. All the pre-set and trimmer condensers should be locked tightly or set with sealing compound. It is not advisable to attempt to re-gang the receiver without special valuable apparatus and expert knowledge.

The Intermediate-frequency Amplifier

To check this circuit, move the wavelength switch to long waves and apply the aerial direct to the grid of the valve. Commercial transmissions may be heard on a wavelength of approximately 2,600 metres, if the volume control is regulated about its centre position. There is very little to go wrong, but if a fault should occur some shorted turns in the anode coil may be suspected. To check the other two coils tuned to this frequency, place the aerial on the grid of the second valve. The signals

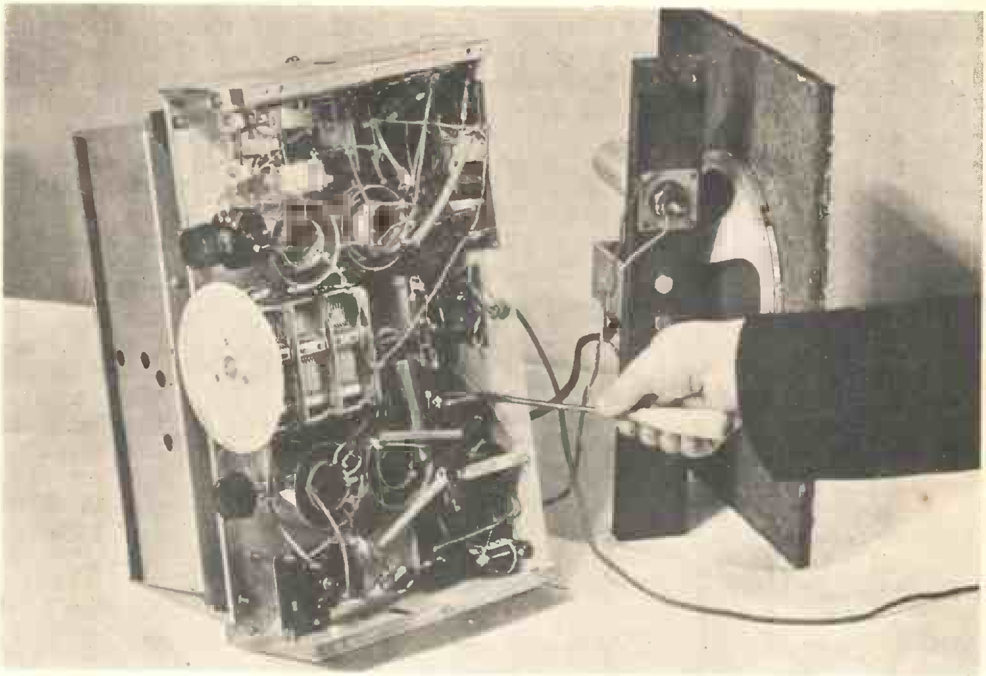


Fig. 7.—Testing the Contacts of the Pick-up Jack.

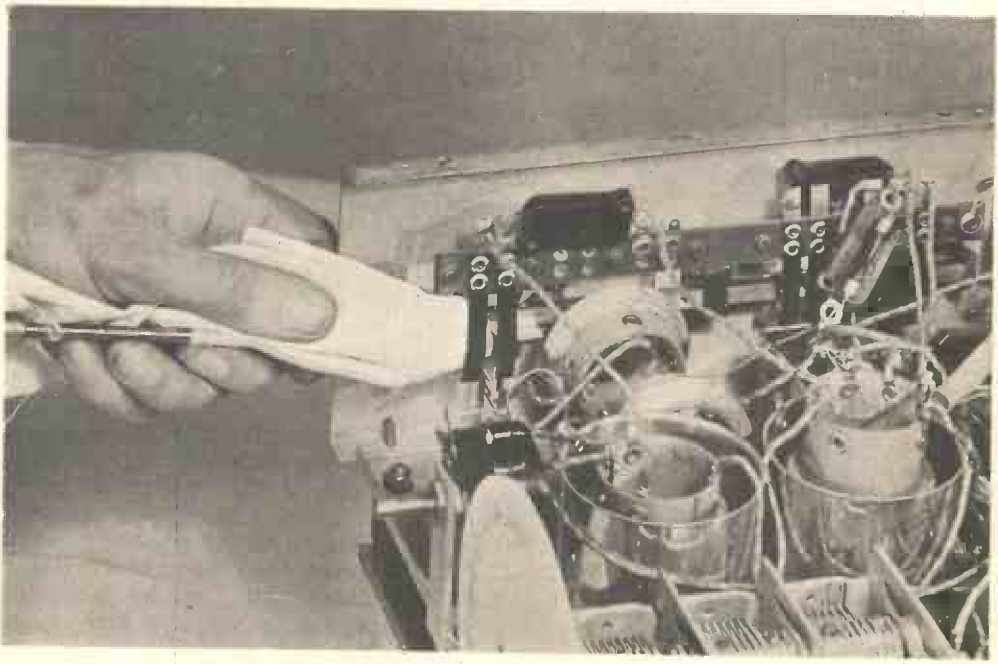


Fig. 8.—Cleaning the Wavechange Switch Contacts.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

SHORT WAVE SUPERHETERODYNE

HOW TO OBTAIN SELECTIVITY

MEASURING INSTRUMENTS

SERVICING KOLSTER-BRANDES RECEIVERS

1/-

Part 27

IN 32 WEEKLY PARTS

PART 27.

previously received should now come in at greater strength.

Checking the First Detector

At this stage the aerial may again be used, but the signals received will be at broadcast frequencies. The H.F. transformer circuit is checked by placing the aerial on the anode of the H.F. valve. Faults may occur in the wave-length switch due to dirty contacts or through open-circuited points in the special jack on the short-wave panel. Check the two ·005 mfd. fixed condensers and the 600-ohm resistance joining the earth end of the H.F. transformer secondary winding to the chassis (see Fig. 9).

Checking the H.F. Valve

Now the aerial may be connected to aerial socket No. 1 on the board at the back of the chassis. If the aerial tuning circuit is faulty touch the aerial lead on the grid of the first valve. This will check the aerial coupling coil and the potentiometer. Any one of the three trimmers of the gang condenser can be tested for short-circuit to earth by removing the coil connection and applying a circuit tester to the fixed and moving plates. Be careful not to alter the adjustment of the vanes or trimmers. If a megger is available it is useful to check each section of the gang condenser for partial short-circuit between the vanes. Dust in the vanes will give rise to considerable noise when the condenser is rotated, particularly if it is the oscillator section which is at fault. Failing a megger, a useful test can be made by using the mains supply with a lamp in series. *All earth, aerial and other connections must be removed and the usual precautions taken where the mains supply is used* (see Fig. 10).

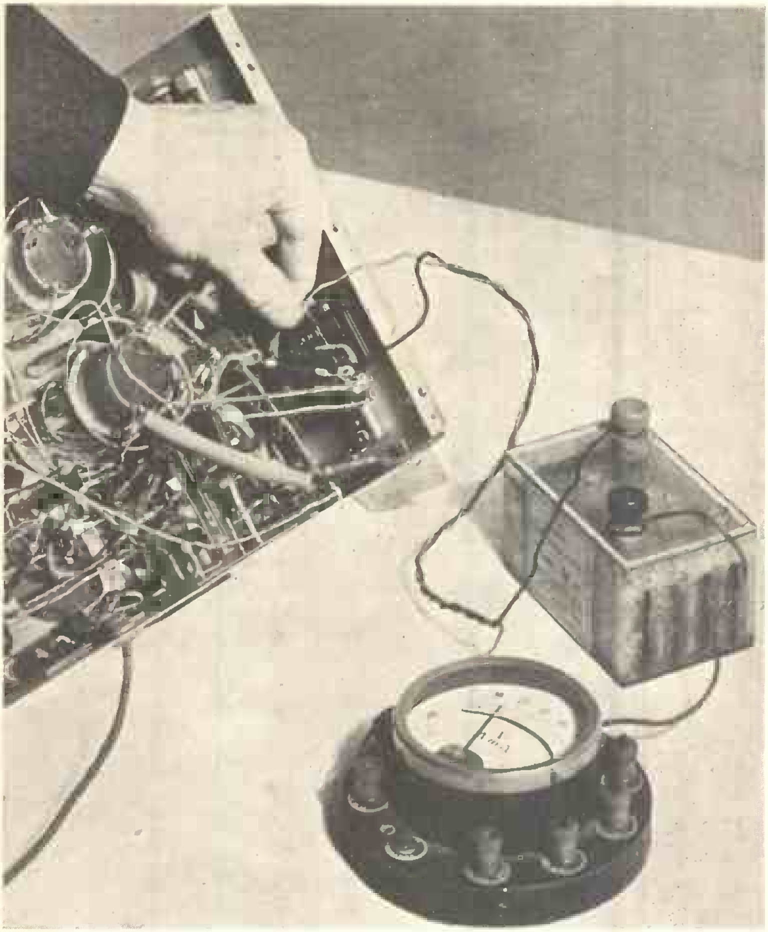


Fig. 9.—CHECKING THE 600-OHM RESISTANCE AND THE SHUNTED CONDENSER CONNECTED TO THE H.F. TRANSFORMER.

Short-wave Reception

Check the continuity of the short-wave coils as indicated in the theoretical diagram. Care must be taken to ensure good electrical contact by pressing the coil firmly into position. Check that the short-wave jack contacts open fully when the coil is fitted. Tuning adjustments will be very critical and care must therefore be taken not to sweep past a signal by rapid rotation of the dial. On ultra-short waves, the tendency to microphonic feed-back is very pronounced. It is often advisable to use an external loud speaker only, particularly on the 16–38 metre waveband.

Mechanical Adjustments

Before returning the chassis to the cabinet, it is advisable to apply a little lubricating oil of good quality to the driving spindle of the gang condenser (see Fig. 11), and to the end bearings of the wavelength switch. A slipping dial can be cured by shortening the driving cord. If the dial is removed during this process, it should be replaced in exactly the same position in order to avoid any error in the wavelength settings of the receiver.

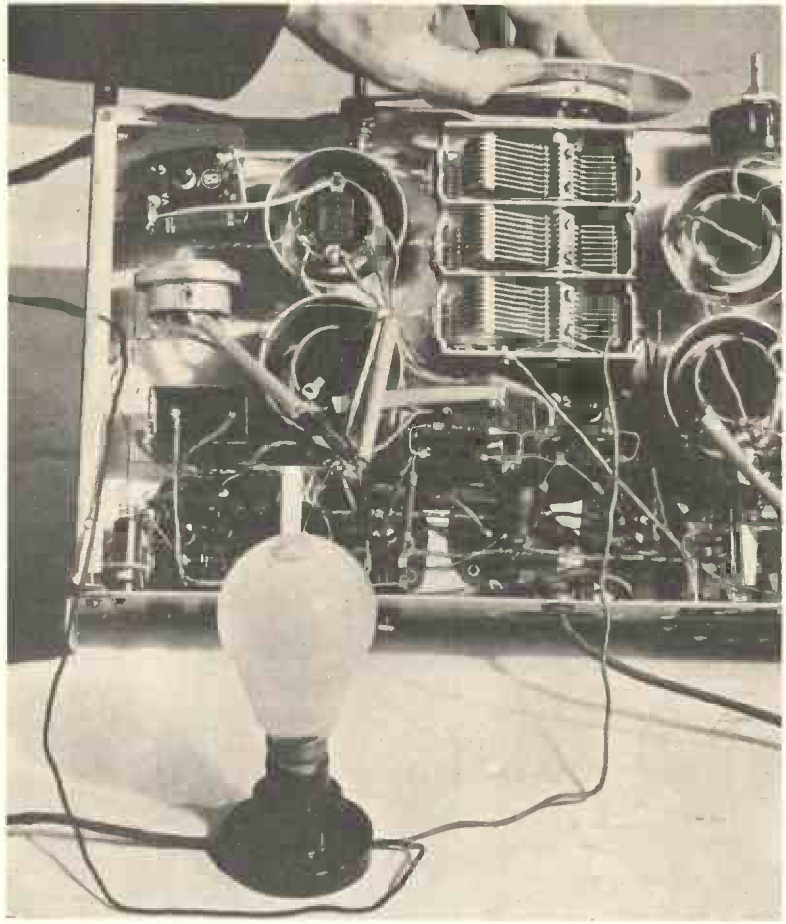


Fig. 10.—A Test for the Presence of Metallic Dust between the Ganged Condenser Plates.

The Reassembly of the Chassis

The correct order for reassembling the various parts to the cabinet is exactly the reverse to the instructions given for removing the chassis with one exception. The wavechange switch lever should be fitted and the Parker Kalon screws tightened before the baffle board and loud speaker unit is returned to position. See that the wavechange switch is set so that the lever hole may be seen through the oblong opening in the chassis. A small brass collar fits over the lever fixing screw. To prevent this collar from slipping off the screw when assembling the lever, bind it in position with a piece of cotton (see Fig. 4). After the screw threads have engaged with the tapped hole in the wavechange switch, the cotton can be removed.

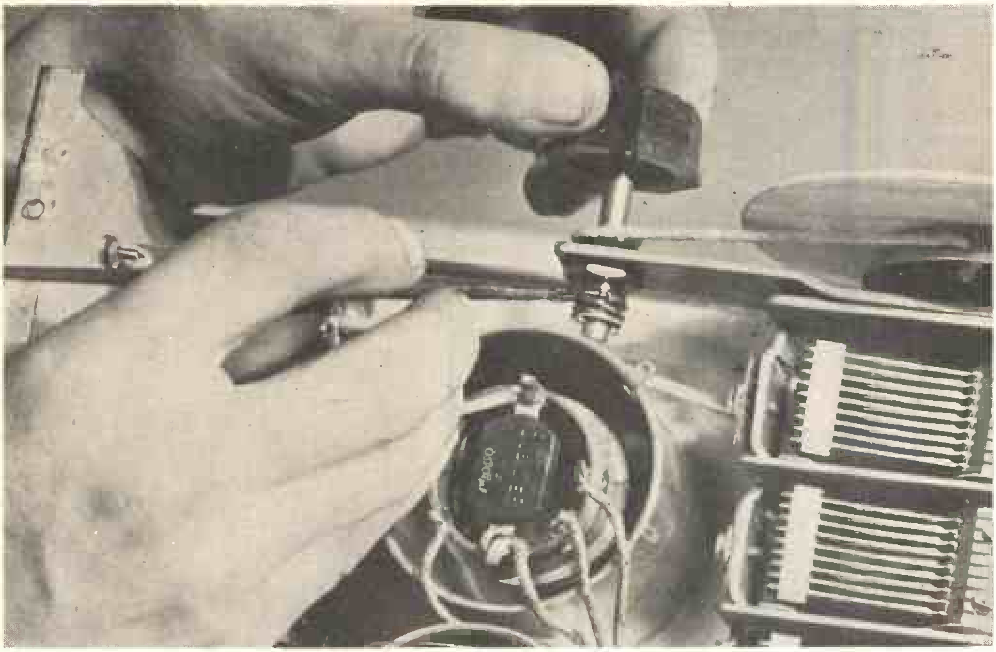


Fig. 11.—Oiling the Driving Spindle of the Ganged Condenser.

Kolster-Brandes Models 285 *and* 286. *Valve Table. Readings approximate only.*

Position in Set.	Valve.	Anode Volts.	Screen or Priming Grid Volts.	Grid Bias.		Anode Current.	Function.
				Ohms.	Volts.		
1	Mullard S4VB or Micromesh S.G.A.1 (metallised)	180	75	600	1·4	2	H.F. amplifier
2	Ditto	170	75	2,500	2·3	·5	1st detector
3	Ditto	170	75	600	1·4	1·5	Intermediate frequency amplifier
4	Mazda AC/HL or Micromesh H.L.A. 1, or Micromesh H.L.A.2 .	170	—	0	0	3·6	Oscillator
5	Mazda AC2 or Micromesh H.L.A.1 or Micromesh H.L.A.2 (metallised)	125	—	300	·6	2·4	2nd detector, first-stage pick-up
6	Mazda AC/Pen . .	200	210	250	8·8	28	Power output
7	Full wave Rectifier Philips	1807	or Micro	mesh R.	2.		

THE KOLSTER - BRANDES FOUR VALVE RECEIVER, MODEL 320 FOR A.C. MAINS

A good example is found in this model of the latest methods of receiver design and construction. Thick steel pressings riveted together form the chassis, on which is mounted every component, including the mains switch and the loud speaker. This system has the advantage of great accessibility for servicing, as not a single wire need be disconnected when the chassis is removed from the cabinet. Furthermore, the resistances and fixed condensers are fitted into spring clips, from which they may rapidly be removed for inspection or test. Access to the scale illuminating lamp is obtained without removing the chassis. The lamp bracket is attached to the rectangular plate bolted by two Parker-Kalon screws to the centre of the vertical partition. By removing these screws the lamp assembly can be withdrawn sufficiently to inspect or renew the lamp.

The Circuit

The theoretical diagram shows that two stages of H.F. amplification coupled by tuned transformers are used, the condensers being ganged for single-knob control. Screened-grid valves of the variable-mu type are employed in both H.F. stages, but for optimum regulation of the volume control in all areas of reception, only the second stage is fitted with variable bias. The bias of the first valve is determined by the 400-ohm resistance, wired direct from the cathode valve-leg to the earth socket. The selectivity of the receiver is well maintained by the use of differential reaction applied to the detector grid circuit.

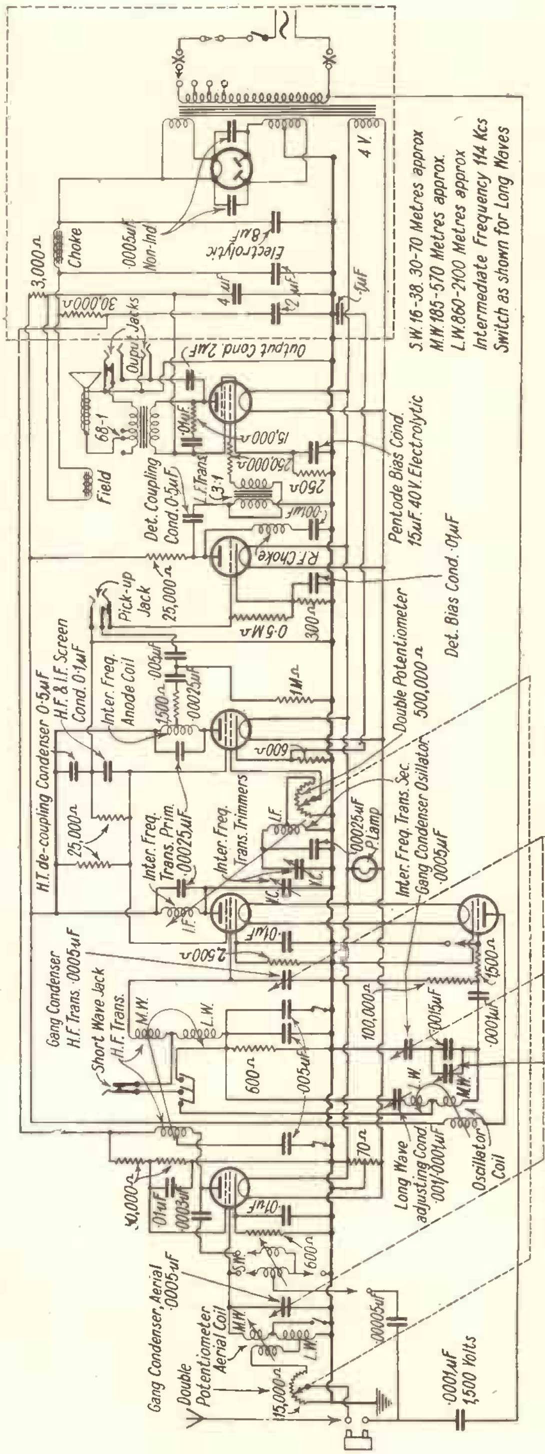


Fig. 12.—Theoretical Circuit Diagram of the Kolster-Brandes Receiver, Models 285 and 286.

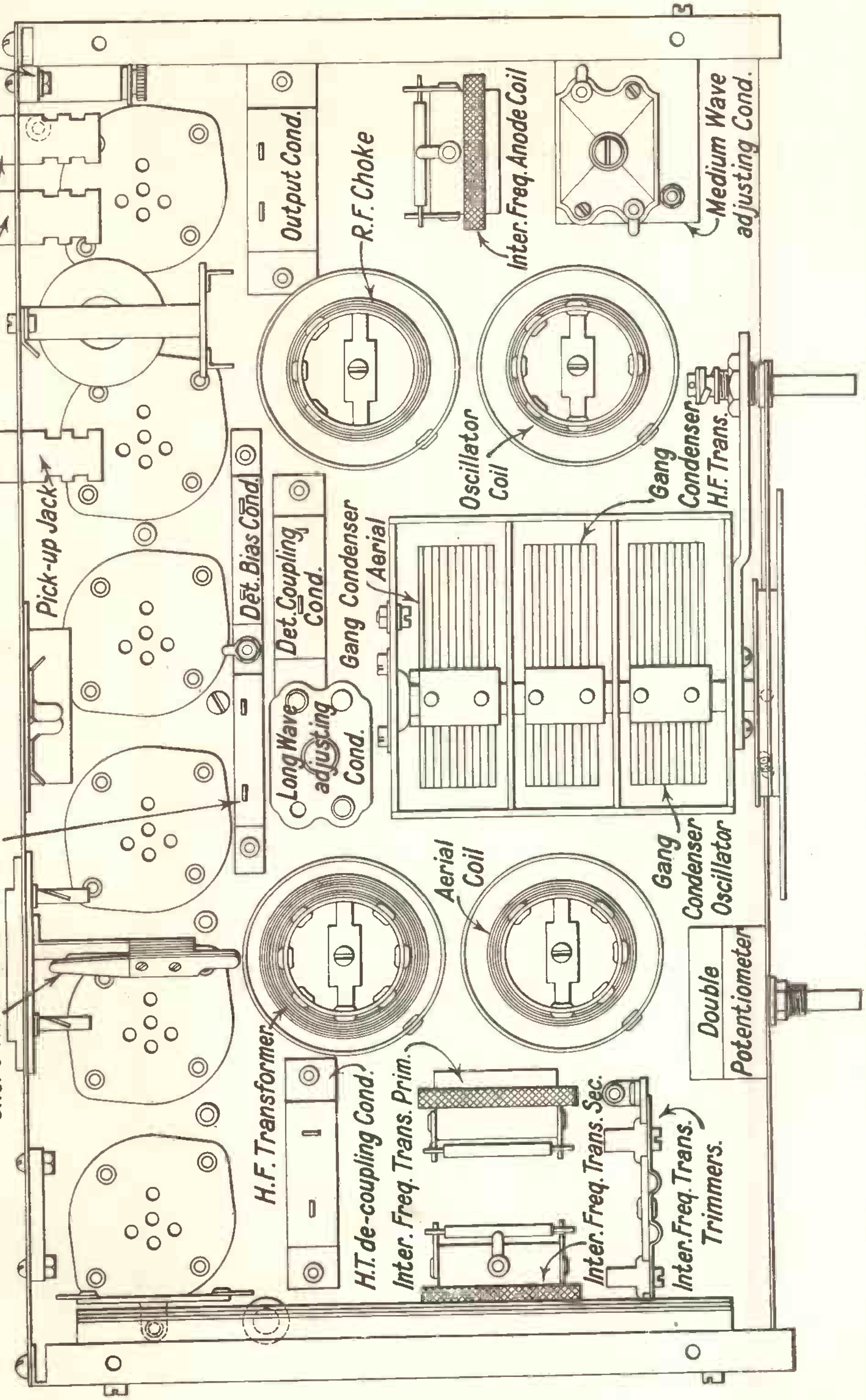


Fig. 13.—Underside of Chassis showing Positions of Components.

Resistance capacity coupling is used between the detector and the pentode output valve with a 4–1 step-up auto-transformer. The mains transformer is of universal voltage.

Removing the Chassis

The reaction and tuning control knobs at the front of the cabinet are removed by passing a loop of tape or the edge of a duster round the back of each knob and then pulling steadily outwards until the knob slides off the spindle (Fig. 14). The combined mains switch and volume control knob at the left side of the cabinet, and the wave-change switch knob on the right side, are removed by loosening the screws from the back or from the holes provided underneath for this purpose (see Figs. 15 and 16).

If metal corner-brackets are fitted at the back of the cabinet only the two lower ones need removing. After the four Parker-Kalon screws have been taken out from the underside of the base, the chassis is tilted backwards at the top edge to clear the top brackets while it is being drawn forwards for removal (see Fig. 17). It may be necessary to move the chassis a little from one side to the other, in order that the projecting spindles of the two side controls clear the side escutcheons. These need not be removed.

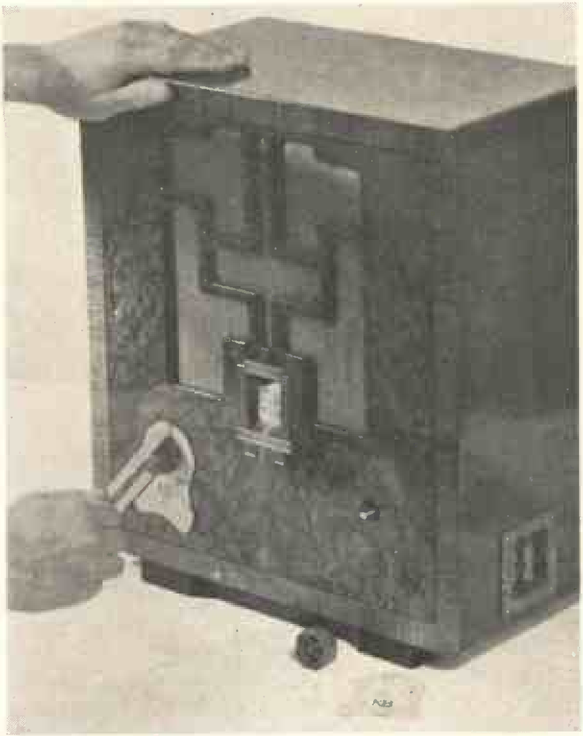


Fig. 14.—Showing the Easiest Way of Removing the Control Knobs on the Kolster-Brandes Receiver, Model 320.

Inspecting and Checking the Interior

With the exception of the pentode valve, a short-circuit in any of the anode or screened-grid leaks is detected by the overheating of one or more of the fixed resistances. These should be a tight fit in their clips. A check on this is made by moving each clip outwards slightly with the end of a screwdriver. If proper contact is being made by the other clip, it should follow the movement of the first one, keeping the resistance firmly in position (see Fig. 18). If the second side of the spring clip is under-tensioned, the resistance will drop in its clips when one side of the latter is opened outwards.

To tighten the resistances remove them from their clips, and bend the latter very carefully inwards with the aid of a small pair of pliers. It is better to make a small bend towards the lower end of the resistance, rather than to attempt to bend further the original elbow (see Fig. 19). A broken clip can be repaired by soldering it at the break with a sharp-pointed iron, leaving plenty of solder at the joint.

To check slipping of the gang condenser drive, replace the control knob and rotate it slowly from one end of the wavelength scale to the other. Any tendency to slip can be cured by tightening the driving cord. Rotate the condenser until the flat

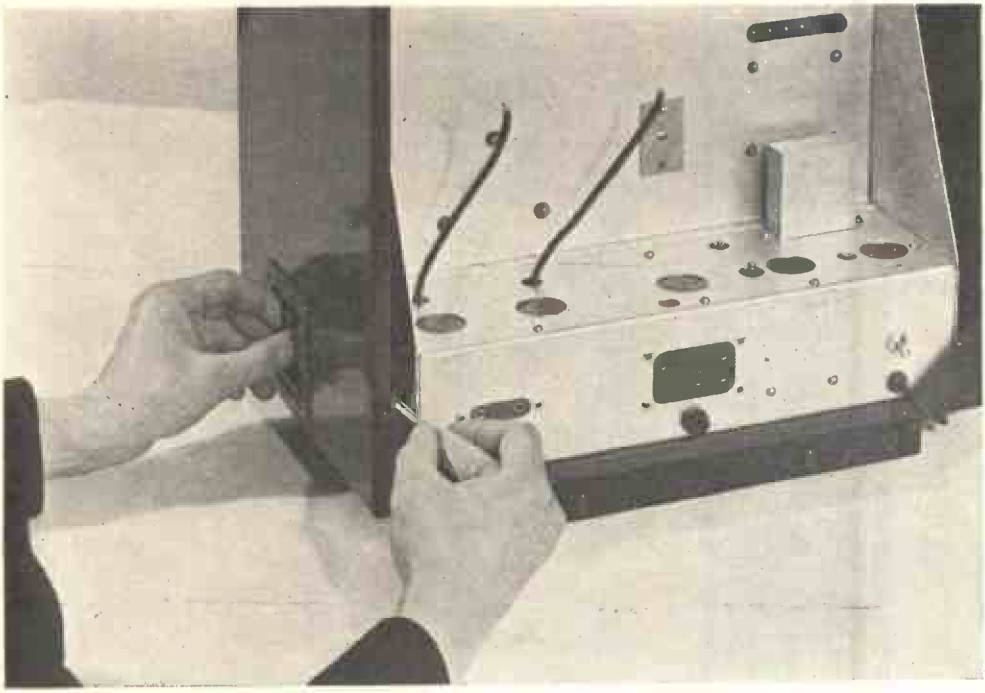


Fig. 15.—How the Side Control Knobs are removed.

Fig. 16.—How the Side Control Knobs are removed.

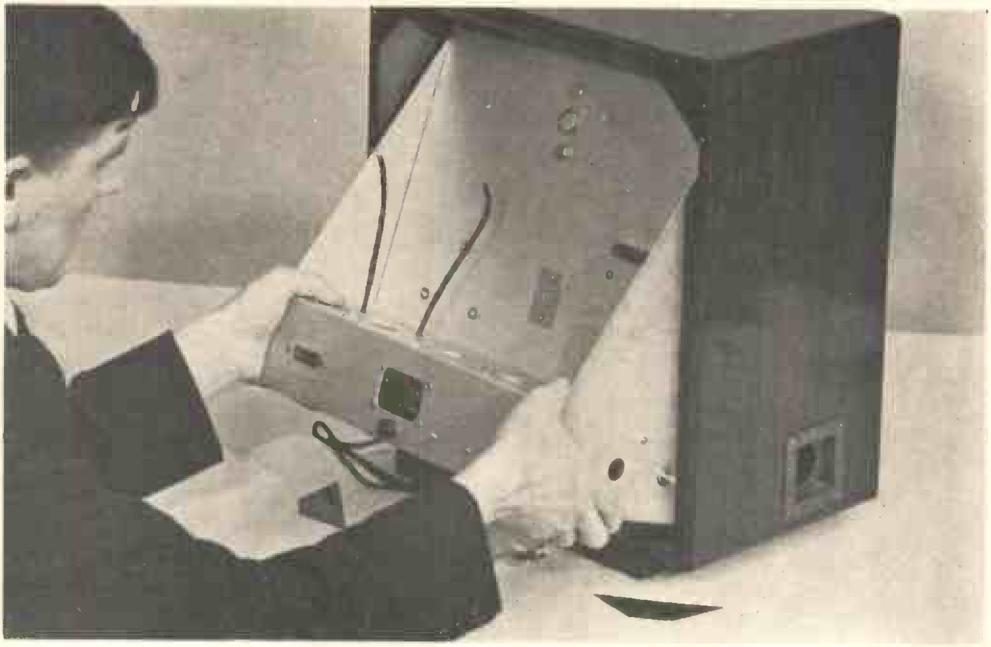


Fig. 17.—Tilting the Chassis during Removal.

Fig. 18.—Checking the Tightness of the Resistances.

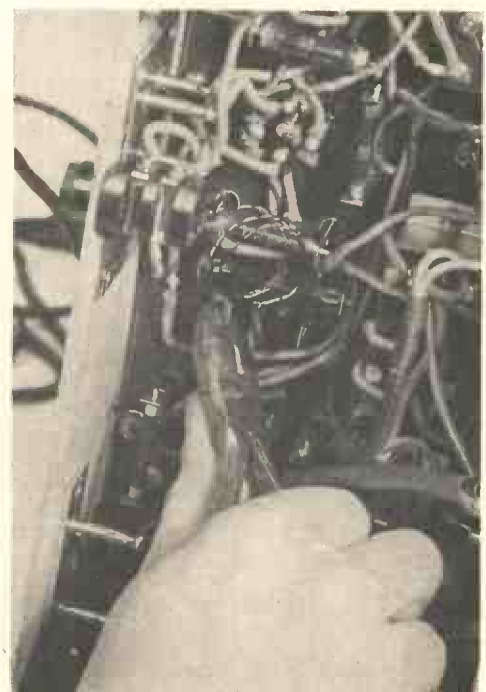


Fig. 19.—Increasing the Tension on the Resistance Clips.

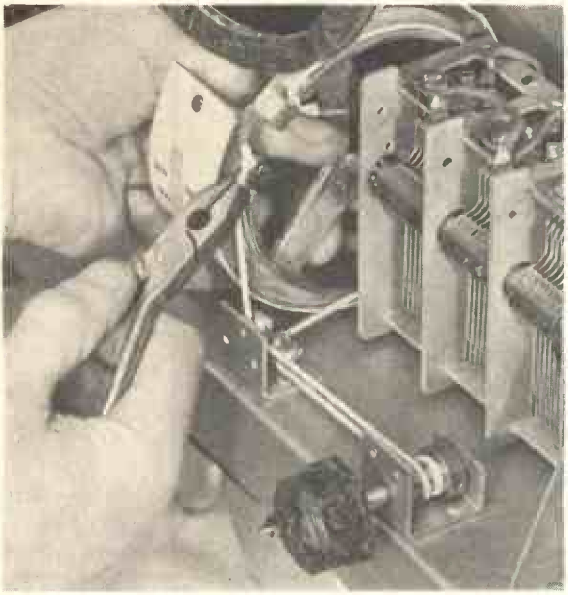


Fig. 20.—TIGHTENING THE GANG-CONDENSER DRIVING CORD.

Fig. 21.—USING AN EAR-PIECE TO CHECK THE L.F. CIRCUITS.

spring fixed to the scale drum is in an accessible position. One end of the cord is secured by a knot into the forked end of the spring. Slacken the spring and remove the end of the cord. The knot is shifted a little further along the cord and replaced in its fork when the spring is approaching its maximum tension (see Fig. 20). In lubricating the two jockey pulleys and the spindle of the cord driving drum, take care that no oil comes into contact with the drum or cord.

The voltage, current and grid-bias resistance values may be checked from the valve table. One or two slight modifications have been made in the value of the minimum bias settings of the H.F. valves since this receiver was first introduced. Any small variations in these readings can be accepted as having no bad influence on the operation of the set.

An excessive audible hum, combined with high-voltage readings, suggests a low-resistance field coil in the loud speaker due to short-circuited turns. The voltage drop across the field coil when the receiver is working correctly should be about 83 volts.

The Output Circuit

Failure of the H.T. supply to the anode of the pentode valve only is traceable to an open-circuited primary winding of the output transformer or to the connecting wires. The lack of voltage generally, not accompanied by obvious signs of an over-loaded mains transformer, points to similar trouble in the field coil or its connections. Overheating of

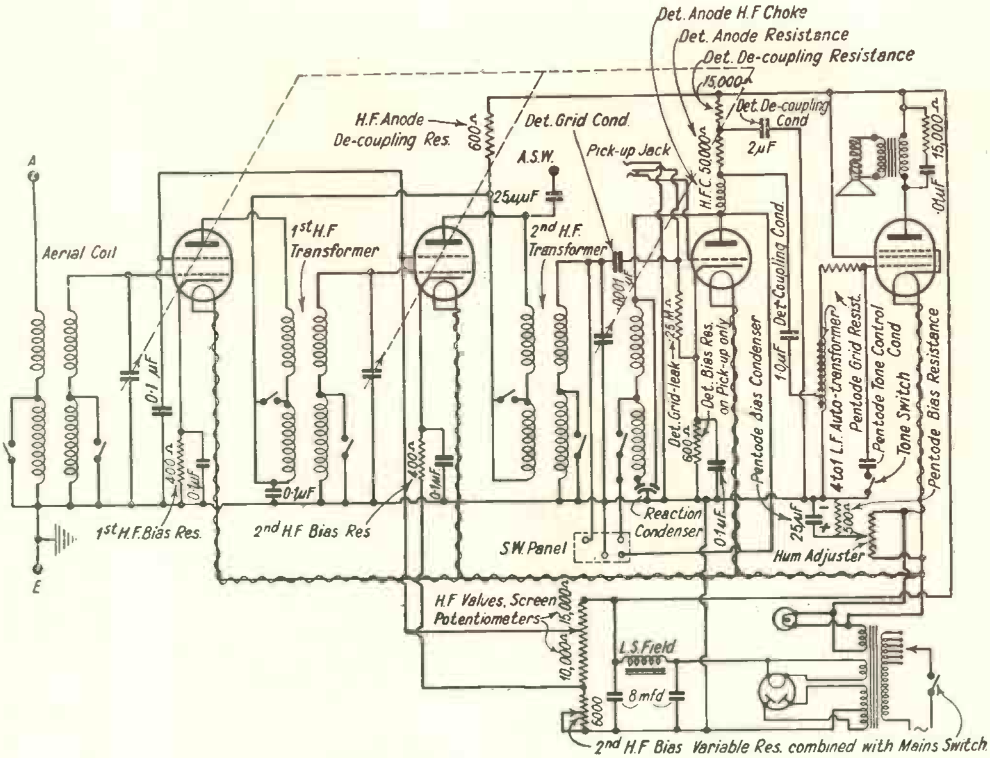


Fig. 22.—THEORETICAL CIRCUIT DIAGRAM OF KOLSTER-BRANDES RECEIVER, MODEL 320.

the mains transformer may be due to the selection of an incorrect mains voltage tapping, a faulty rectifier or a short-circuit in the heater or H.T. circuit. Positive grid potential to the pentode will occur if the coupling condenser from the detector anode to the auto-transformer is short-circuited.

The Detector

To check the detector circuit, plug-in a telephone plug to the pick-up jack,

KOLSTER-BRANDES MODEL 320. VALVE TABLE SHOWING VOLTAGE, CURRENT AND BIAS VALUES

Valve No.	Anode Volts.	Anode Current m.a.	Screen or Priming Grid Volts.	Bias. Negative Volts.	Bias. Resistance.	Function.	Type.	Alternative.
1	210	6	76	1·8	400	1st H.F. amplifier.	Cossor MVSG (Met.).	Micromesh VSGA1 (Met.).
2	210	5	76	1·8–20	400–6400	2nd ,, ,,	Cossor MVSG (Met.).	Micromesh VSGA1 (Met.).
3	74	2	—	·6	600 P.-Up.	Detector and 1st stage pick-up.	Cossor 41 MH (Met.).	Micromesh HLA2 (Met.).
4	210	25	216	14	500	Output stage.	Cossor PT41.	Micromesh Pen. A1.

Readings are approximate only and taken with volume control at maximum setting.
Rectifier Cossor 442BU or Micromesh R2.

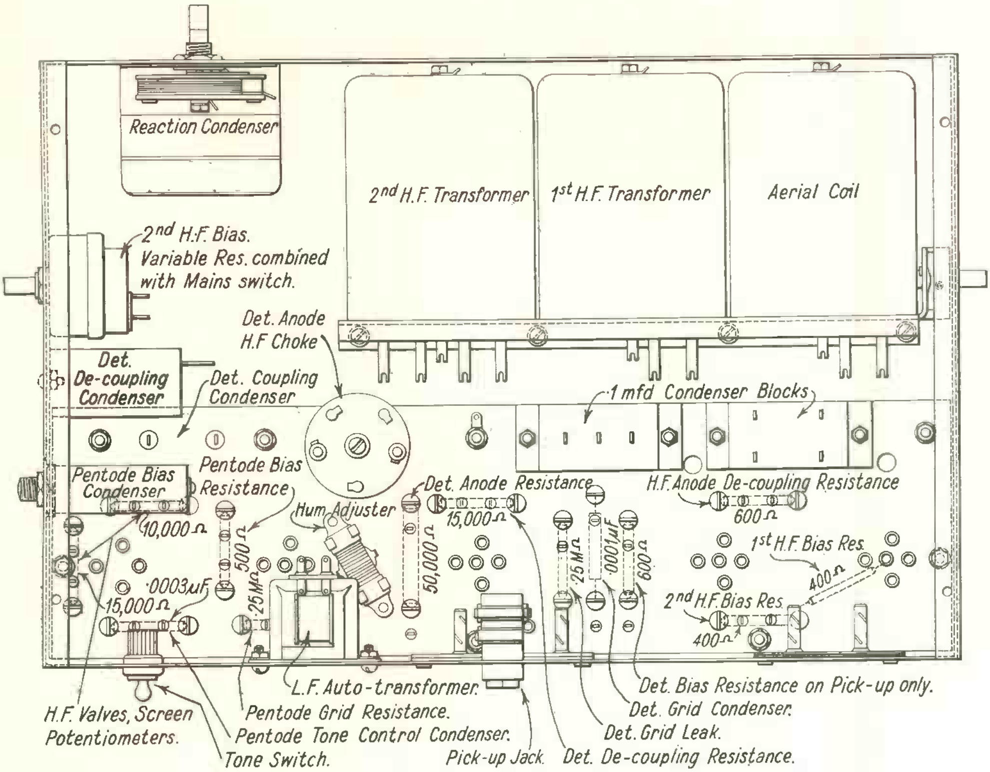


Fig. 23.—UNDERSIDE OF CHASSIS SHOWING POSITION OF COMPONENTS.

connecting either a telephone ear-piece or a pick-up to the former. The ear-piece is a useful accessory for testing from the detector stage to the output. It is used as a microphone, and, if placed adjacent to the loud speaker, a continual note or whistle is obtained, due to the effect known as acoustic reaction (see Fig. 21). Check the jack points for continuity if the set operates on the pick-up jack and not on the radio side. Weak signals may be due to faulty bias resistances or shunted condensers. The former should be checked, however, by the voltage tests.

The Second H.F. Stage

Irregularities in the operation of the volume control will be shown by a lack of smoothness when checking the bias voltage from the grid and cathode valve-sockets of this stage. The valve table gives the range of bias voltages which may be expected, and the increase from minimum to maximum should be steadily progressive as the volume control is rotated. A sudden increase in bias reading occurs if the moving contact of the volume control becomes open-circuited or of poor contact. In both H.F. valves the bias is kept slightly negative by the fixed resistances of 400 ohms. Excessive oscillation may be traced to the failure of the anode or screened-grid decoupling condensers. A short circuit in either of these will cause the 600- or 15,000-ohm resistances to overheat.

The First H.F. Stage

There is very little in the aerial circuit or its associated valve to give rise to any particular fault. It may be checked by placing the aerial on the valve anode terminal and tuning in a signal. Transfer the aerial to the grid to check the valve and the gang condenser for short circuit, and finally on the aerial terminal.

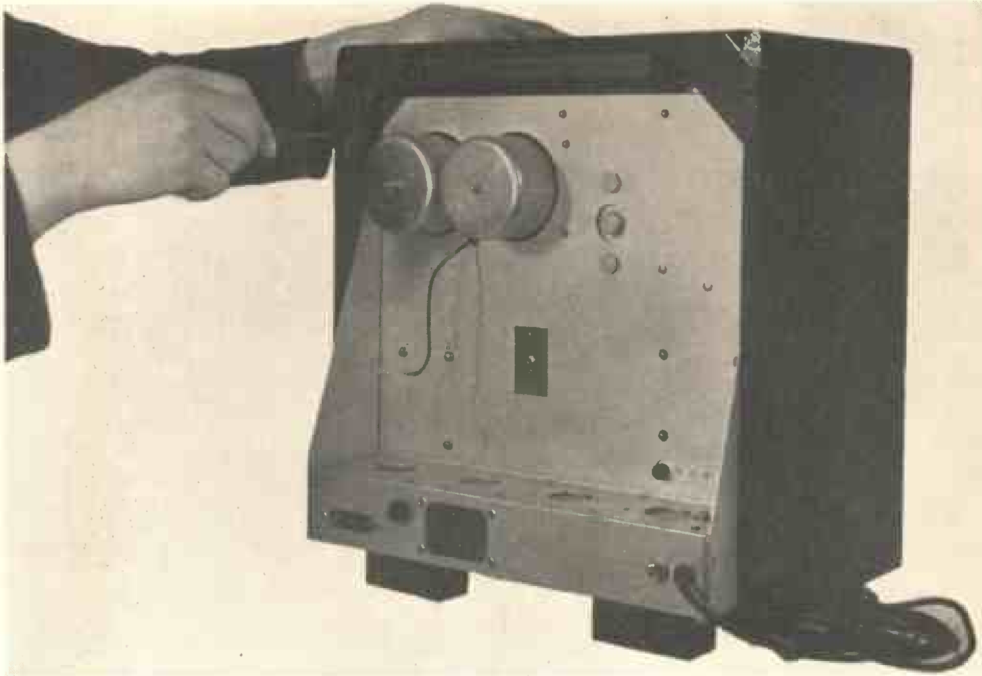


Fig. 24.—REMOVING THE CORNER BRACKETS OF THE KOLSTER-BRANDES RECEIVER, MODEL 321.
In this model the corner brackets are removed before taking out the chassis.

THE KOLSTER-BRANDES 3-VALVE ALL-MAINS RECEIVER, MODEL 321

General Description

The problems confronting the designer of a three-valve receiver are often more difficult of solution than those of a multi-valve set. It follows that the greater the number of H.F. valves, with corresponding tuned circuits, the greater will be the selectivity obtainable. The higher amplification secured with the use of one extra H.F. stage enables the designer to throw

KOLSTER-BRANDES MODEL 321. TABLE OF VOLTAGE, CURRENT AND BIAS VALUES.

Valve No.	Type of Valve.	Alternative.	Anode Volts.	Screen Volts.	Grid-bias Res.	Bias Volts.	Anode Current.	Function of Valve.
1	Mazda AC/S2	Micromesh SGA1 Met.	230	78	250	1·75	6 m.a.	H.F. Amplifier
2	Cossor 41 MHL	Micromesh HLA1 or HLA2 Met.	78	—	— On pick-up 600	— ·8	2·4 m.a.	Detector 1st stage pick-up
3	Osram PT4	Micromesh Pen. A1	240	250	450	14	28 m.a.	Pentode output
4	Rectifier Micromesh R2 or Philips 1807							

away some sensitivity in favour of increased selectivity, obtainable by loose coil coupling and general coil design. In the majority of three-valve circuits it is not advisable to sacrifice signal strength to any extent if reception of more distant stations is expected.

The aerial primary circuit of the Kolster-Brandes 321 receiver includes a differential variable condenser connected at its two fixed sets of vanes to the aerial and earth sockets. The moving vanes connect, through a rejector coil, to the primary winding of the aerial coil. Thus the differential condenser forms an aerial volume control and permits the reduction in volume of a signal which might interfere with the reception of a required programme. This control is used

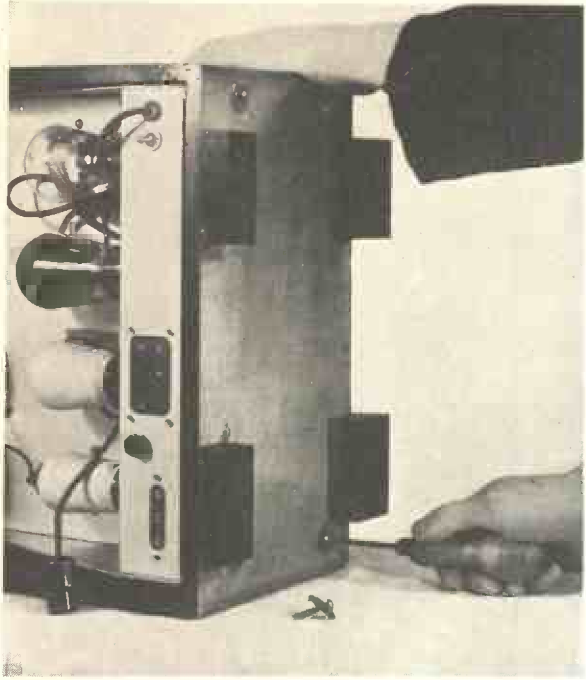


Fig. 25.—Removing the Four Screws from Underneath the Cabinet.

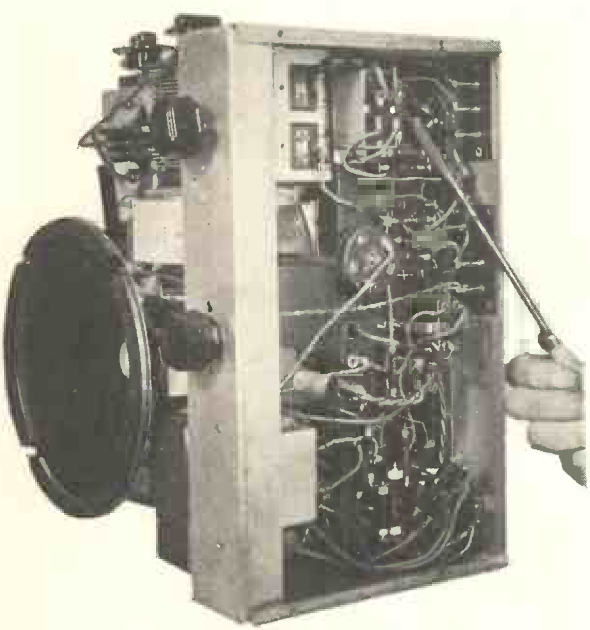


Fig. 26.—Shorting a Heater Lead to Chassis to Check the Insulation of this Circuit.

in conjunction with a differential reaction condenser which restores the sensitivity lost in decreasing the aerial input strength, an operation which may be necessary for increasing selectivity.

The Rejector Coil

This coil is in series with the moving vanes of the aerial differential condenser and the aerial coil. On the medium broadcast band the rejector coil is shorted across by the switch contacts. On long waves the rejector coil forms an H.F. choke which prevents a powerful station on the medium waveband from breaking through and spoiling reception.

The Detector Circuit

Transformer coupling tuned on the grid coil is again employed between the H.F. and detector valve. The short-wave coil is connected in parallel with the tuned-grid coil and the reaction coil respectively. The detector biassing resistance of 600 ohms is shorted out on the radio side, but comes into operation when the gramophone jack is inserted. Both the tuned H.F. circuits are controlled by a twin gang condenser operated by cord drive from the right-hand control knob at the front of the set. The second of these controls the reaction adjustment. The

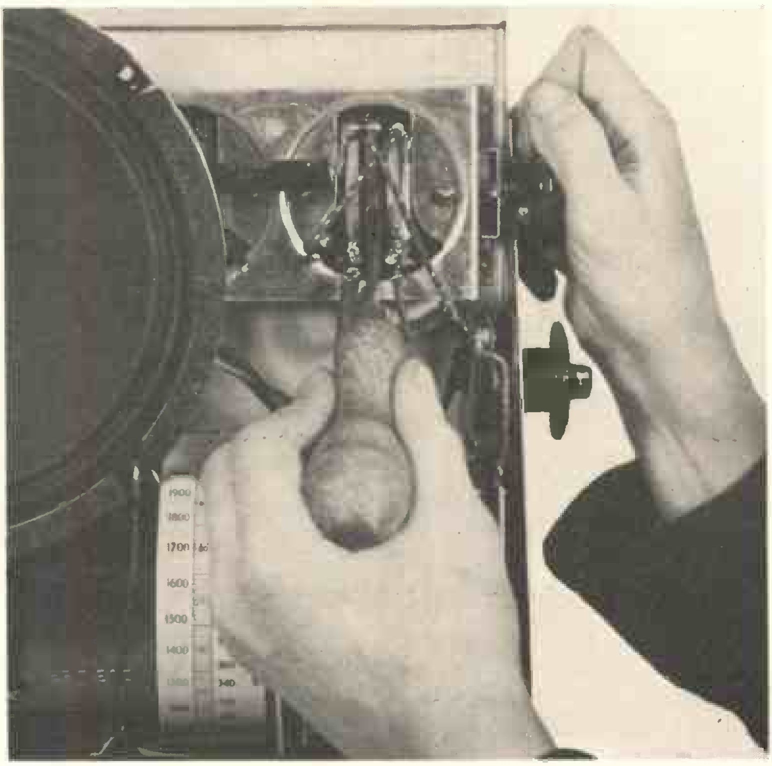


Fig. 27.—Checking the Contact Blades of the Wave-change Switch.

wave-change switch is at the top of the side-control escutcheon with the variable input control below it.

The Pentode Circuit

The detector valve is coupled to the pentode by the resistance capacity method with a step-up auto-transformer in the grid circuit. The circuit diagram shows a coil coupled to the loud-speaker field coil and in series with the secondary winding of the output transformer and the speech coil of the loud speaker. This coil is the "hum bucking coil," its object being to neutralise any mains hum effect due to the use of the field coil as a smoothing choke. A small condenser is wired from each side of the rectifier heater winding to each plate of the rectifier valve. Their function is to prevent modulation hum.

Dismantling the Chassis

Before removing the chassis, the tuning control should be rotated to the minimum reading and a note taken of the scale setting opposite to the hair-line across the middle of the escutcheon. The object of this is to preserve the accuracy of the wavelength calibration if it is found necessary to move the wavelength drum at a later stage. There are no fixing screws to the two front control knobs; instead, a flat spring held internally presses against a flattened face on each control spindle. An even pull outwards is required to remove the knobs, and assistance may be gained by wrapping the edge of a duster round the knob to obtain a better grip.

If corner plates are fitted to the top of the cabinet back, these must be removed before the chassis can be taken out for examination (see Fig. 24). The latter is bolted in position by four Parker Kalon screws passing through the base of the cabinet. Remove the two side-control knobs by means of a long screwdriver passing between the inside of the cabinet and the corresponding side of the chassis. The interior can be withdrawn when its fixing screws have been removed (see Fig. 25).

Voltage and Current Values

A table of voltage and current values for the various valves is given on p. 1268. If the values do not check up correctly, the fault can be traced to a particular part of the circuit without difficulty. Excessive hum may be caused by a short-circuit on either side of the valve heater circuit. To check this, short-circuit to the chassis, the heater sockets in turn of any one valve holder except the rectifier, which must not be touched. If a short-circuit exists, its presence will be detected (by the intentional short - circuit) by the dimming of the pilot lamp as the heater winding takes the extra load imposed upon it. This fault may be suspected if the hum adjuster appears to be inoperative (see Fig. 26).

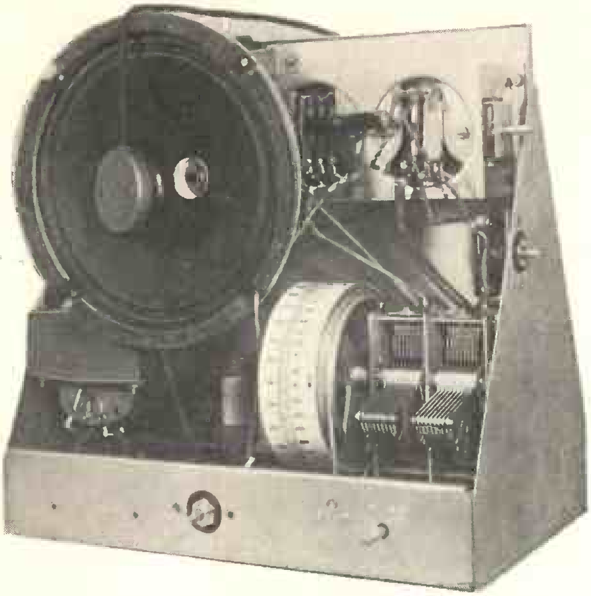


Fig. 28.—How to Provide for Acoustic Reaction in Testing the Low-frequency Circuits.

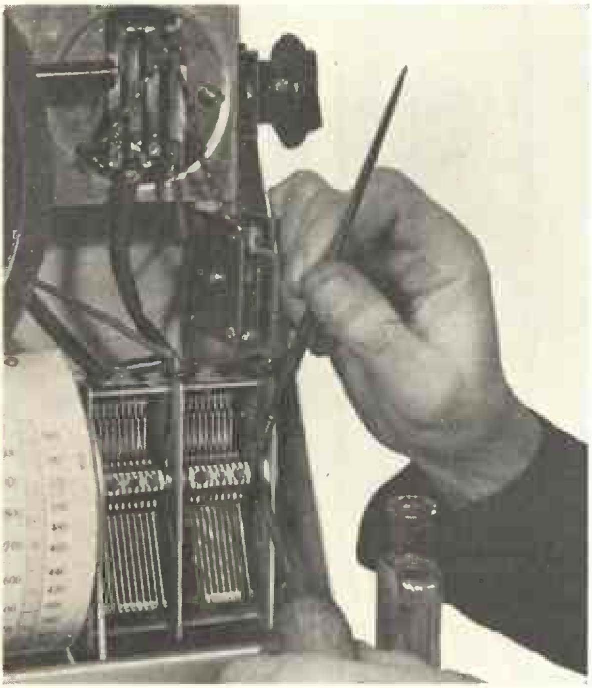


Fig. 29.—Pushing aside the Spring while Oiling the Contacts.

Checking for Loose Connections

Poor electrical contact can usually be detected by an intermittent crackling when the receiver is sharply tapped with the hand. A valve may be at fault or one of the resistances not perfectly tight in its clips. If one resistance clip is pressed slightly outwards, the second one, being under tension, should follow it and keep the resistance still securely held. The clips may be tightened by bending them inwards with the resistance removed. Faulty switch contact will give rise to crackles, and is checked as shown in Fig. 27. The end of a sharp-

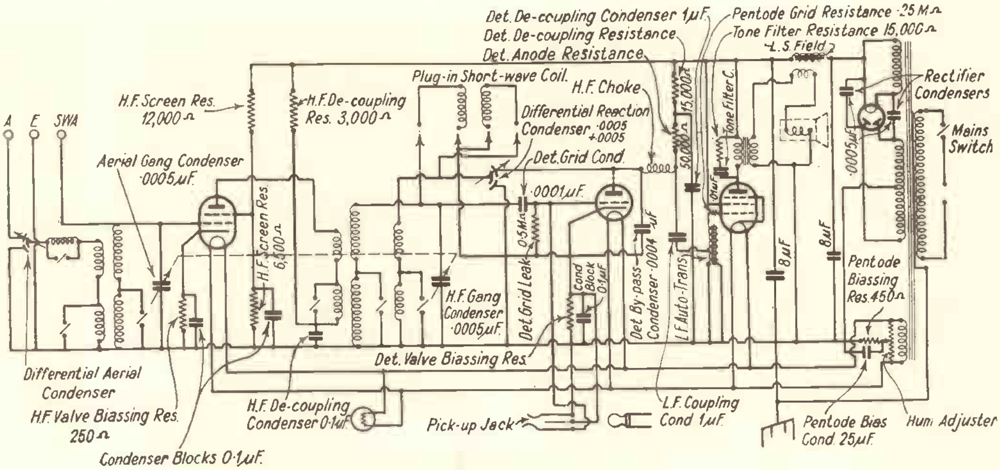


Fig. 30.—THEORETICAL CIRCUIT DIAGRAM OF KOLSTER-BRANDES RECEIVER, MODEL 321.

The aerial primary circuit includes a differential variable condenser connected at its two fixed vanes to the aerial and earth sockets. The moving vanes connect, through a rejector coil, to the primary winding of the aerial coil. Thus the differential condenser forms an aerial volume control and permits the reduction in volume of a signal which might interfere with the reception of a required programme.

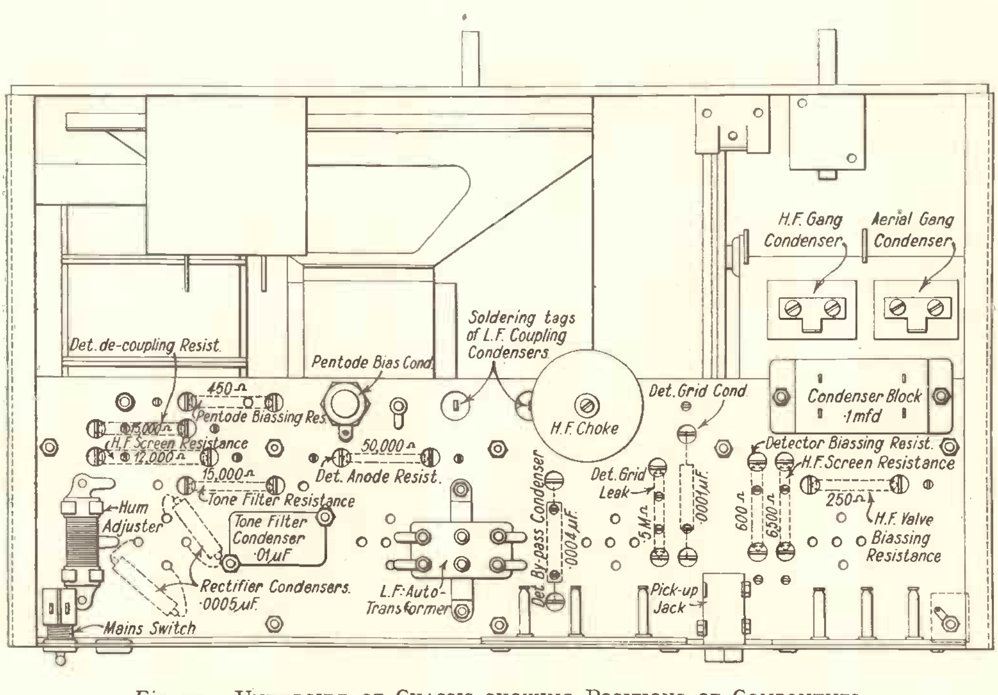


Fig. 31.—UNDERSIDE OF CHASSIS SHOWING POSITIONS OF COMPONENTS.

pointed tool is firmly pressed against the shorter of any two sets of wave-switch contacts. When the switch knob is rotated from long-wave to the medium-wave position, the movement should be felt by the hand holding the tool.

Checking the L.F. Circuit

Failure in the L.F. circuits can be dismissed if the simple test shown in Fig. 28 is successfully completed. An ear-piece is wired to a telephone plug and the latter inserted in the pick-up jack. The ear-piece is suspended close to the loud speaker, which, if the circuits are in order, will give rise to a shrill whistle due to the acoustic coupling between input and output devices.

Lubricating the Moving Parts

While the interior of the chassis is accessible, it is well to inspect the moving parts and lubricate where necessary, taking care that no oil is allowed to come into contact with the cord drive of the gang condenser. A small brush of the type shown in Fig. 29 is useful for this operation. This illustration shows the method of oiling the brass contacts pressing against the moving member of the gang condenser. It will be seen that a screwdriver is used to force the spring backwards, while the brush is applied to the area of contact. It may appear bad policy to apply oil where electrical contact is made, but, in practice, it is found to eliminate crackling noises particularly when tuning on the short waves.

Checking the Radio Side

With the suppression of all undesirable crackles, the H.F. circuits may be checked. Firstly, place the aerial on the anode lead of the H.F. valve and tune in a station. From this point the aerial is transferred to the grid of the H.F. valve, a convenient point being the socket of the short-wave aerial. If the station is received at greater strength, replace the aerial in its proper socket and check the long waves in addition. The rejector coil previously described can be checked for continuity by short-circuiting it as shown in Fig. 32. The theoretical diagram given in Fig. 30 shows that the rejector coil is directly in series with the aerial primary coil.

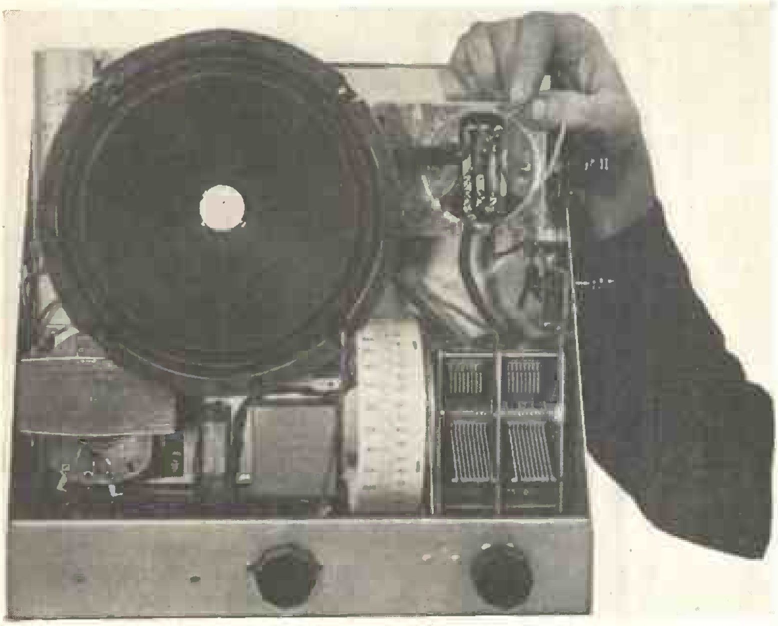


Fig. 32.—Checking the Continuity of the Rejector Coil

A Point to Remember when Replacing the Chassis

Fig. 31 shows a plan view of the underside of the chassis. In replacing the chassis, check that the wavelength scale does not foul the front escutcheon before finally tightening the chassis-fixing screws.

A SHORT-WAVE SUPERHETERODYNE

By **FRANK PRESTON, F.R.A.**

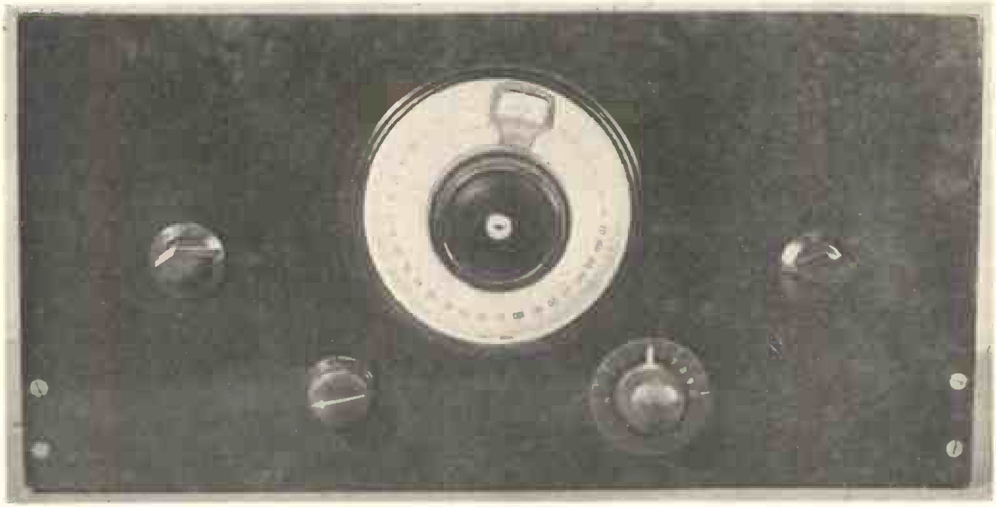


Fig. 1.—The Tuning Controls of the Short-wave Superheterodyne Receiver.

IN a previous article entitled "Short-Wave Reception" I dealt in general terms with the design and construction of short-wave receiving apparatus of a simple character. It is now proposed to give full constructional details of a rather more advanced type of short-wave set. The instrument has been designed specifically as an extremely high-class receiver covering a wavelength range of from rather less than 17 up to 64 metres; it is a superheterodyne and is easily capable of bringing in any short-wave station in the world at good programme strength.

Easy to Operate

Besides being extremely sensitive and powerful, the set is very easy to operate and can be tuned just as easily as a good broadcast receiver of the "family" type. Only a single tuning knob is provided, and once the preliminary adjustments have been made all tuning can be carried out by means of this knob *alone*.

The great advantage of an instrument of this kind is that it may be relied upon to give trouble-free reception over unlimited distances, even under comparatively poor atmospheric conditions. Unlike those receivers designed to cover both long and short wavelengths, this is not a compromise but a real "thoroughbred," capable of performing only a single duty, but of performing it to perfection.

Inexpensive

The set is not expensive, costing less than £6 (without valves and batteries), whilst it is very economical in current consumption. Assuming the use of a 100-volt high-tension battery (which is recommended) the drain will not exceed 7 milliamps, and in consequence a battery of the smallest type will have a reasonably long life. The consumption of low-tension current is rather more than ½ ampere, and, therefore, a 30-ampere hour accumulator will provide some fifty hours of service before recharging becomes necessary.

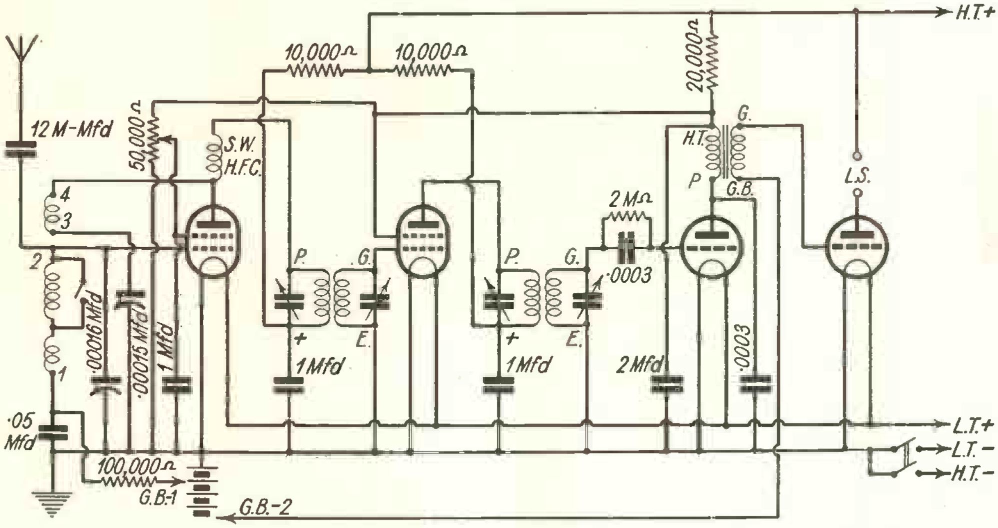


Fig. 2.—THEORETICAL CIRCUIT DIAGRAM OF THE SHORT-WAVE SUPERHETERODYNE.

LIST OF COMPONENTS REQUIRED

- 1 12-m.-mfd. fixed S.W. aerial condenser (*Eddystone*).
- 1 ·00016-mfd. S.W. variable condenser (*Eddystone*).
- 1 Vernier condenser dial (*Utility Micro-Dial*).
- 1 ·00015-mfd. slow-motion reaction condenser (*Eddystone*).
- 1 50,000-ohm potentiometer (*Lewcos*).
- 1 2-pole on-off switch (*Colvern* " S2 ").
- 1 Short-wave H.F. choke (*Bulgin*).
- 1 Screened S.W. Tuner (*Colvern type* " *KSW* ").
- 2 S.W. band-pass intermediate frequency transformers (*Colvern type* "·150 ").
- 4 Sub-panel valve holders (*Eddystone*).
- 3 1-mfd. non-inductive condensers (*T.C.C.*).
- 1 2-mfd. condenser (*T.C.C.*).
- 1 ·05 - mfd. non-inductive condenser (*T.C.C.*).
- 2 ·0003-mfd. fixed condensers (*T.C.C.*).
- 1 2-megohm grid leak (*Dubilier*).
- 1 100,000-ohm metallised resistance (*Dubilier*, 1 watt).
- 2 10,000-ohm metallised resistances (*Dubilier*, 1 watt).
- 1 20,000-ohm metallised resistance (*Dubilier*, 1 watt).
- 1 7 : 1 L.F. transformer (*Varley Rectatone*).
- 2 Twin terminal blocks, one marked " A " and " E," and one " L.S. + " and " L.S. — " (*Lissen*).
- 1 Grid-bias battery clip (*Bulgin*).
- 2 Safety S.G. anode connectors (*Belling Lee*).
- 5 Wander plugs, marked " H.T. +," " H.T. —," " G.B. +," " G.B. — 1 " and " G.B. — 2 " (*Belling Lee*).
- 2 Accumulator spade terminals, marked " L.T. + " and " L.T. — " (*Belling Lee*).
- 1 Polished plywood panel, 14 by 7 inches (*Vibranti*).
- 1 5-ply baseboard, 14 by 10 inches.
- 2 Pieces hardwood, $11\frac{1}{2}$ by $1\frac{3}{4}$ inches by $\frac{1}{2}$ inch.
- 2 Coils " Glazite " connecting wire, short-length flex, screws, etc.

Approximate Cost of above Components, £5 15s. 0d.

- 2 Metallised screened-grid valves (*Cossor* 215 S.G.)
- 1 Metallised detector valve (*Cossor* 210 Det.).
- 1 Small power valve (*Cossor* 215 P.).
- 1 9-volt grid-bias battery (*Drydex*).
- 1 High-tension battery, 108 or 120 volts (*Drydex*).
- 1 L.T. accumulator, type No. C23 (*Exide*).

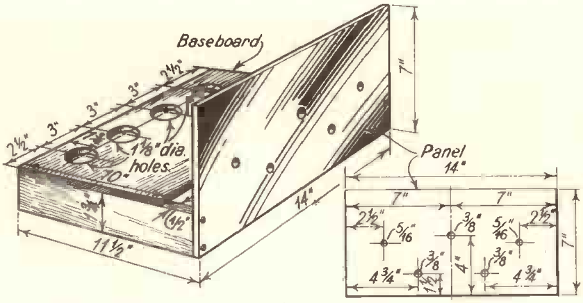


Fig. 3.—Details and Dimensions of Chassis.

Being built on a wooden chassis, the set is easy to construct and is of neat, business-like appearance. The panel is of a standard size, and thus the instrument can be housed in practically any of the cabinets now on the market, if desired. No particular cabinet is specified, since the choice is rather a matter of individual taste.

The Circuit

It is not intended here to explain in detail the principles upon which the superheterodyne functions. Readers who wish to refresh their memory on this side of the subject are recommended to refer back to the article which appears on page 515. In this article an explanation of the manner in which the incoming signals are converted to a lower frequency before rectification is fully explained. Four valves are employed, and they are, respectively, a combined first detector-oscillator, screened-grid intermediate-frequency amplifier, second detector and power output valve.

The circuit diagram of Fig. 2 shows that the whole arrangement is on simple and straightforward lines; not a single unnecessary "gadget" is included. As a matter of fact, various alternative circuits and connections were tried during the experimental period, but optimum results were obtained when the circuit was reduced to its simplest form.

Any Type of Aerial System can be used

A 12-micro-microfarad fixed condenser is included in the aerial lead to reduce any likely damping effect, and as a result the set can be used with entire satisfaction on practically any type of aerial system.

Screened Dual-range Tuner

A screened dual-range tuner is used for tuning the aerial circuit, and this covers the two wavelength ranges of from approximately 16·8 to 32 and 30 to 64 metres when tuned by the ·00016-mfd. variable condenser. The latter is fitted with a 100 to 1 reduction drive to ensure that tuning shall be both easy and accurate.

Reaction

Reaction is controlled by means of a ·00015-mfd. vernier condenser which provides a very smooth regulation of feedback over the whole of both wavelength ranges. A screened-grid valve is used for the first stage, and this acts as a combined "first detector" and "oscillator" on the autodyne principle. Rectification is on the anode bend system, and the necessary grid bias is obtained through a 100,000-ohm decoupling resistance from the common grid-bias battery, a ·05-mfd. condenser serving as a H.F. by-pass between the G.B. tapping and earth.

Potentiometer for Controlling Screening Grid Voltage

So as to ensure that the first valve shall operate under the most efficient conditions, its screening grid is supplied with high-tension voltage through a 50,000-ohm potentiometer which may be set to its optimum position whilst the receiver is in use. The potentiometer is also extremely useful as a means of obtaining a very delicate and final adjustment of reaction.

High-frequency Choke

A short-wave high-frequency choke is inserted in the anode circuit of the first valve to prevent the passage of signal frequencies into the amplifier. As is the case with any superheterodyne, it is the purpose of the oscillator valve to convert the short-wave signal impulses into others of longer wavelength which can be amplified by the intermediate-frequency valve.

With the set under discussion the intermediate frequency adopted is 150 kilocycles, which corresponds to a wavelength of 2,000 metres ; the two band-pass H.F. transformers are therefore self-tuned to this frequency. As, however, some little variation might occur due to the capacity of the wiring, both primary and secondary windings are provided with small pre-set condensers so that they may be matched with perfect accuracy when the set is first tested ; no later adjustments need then be made.

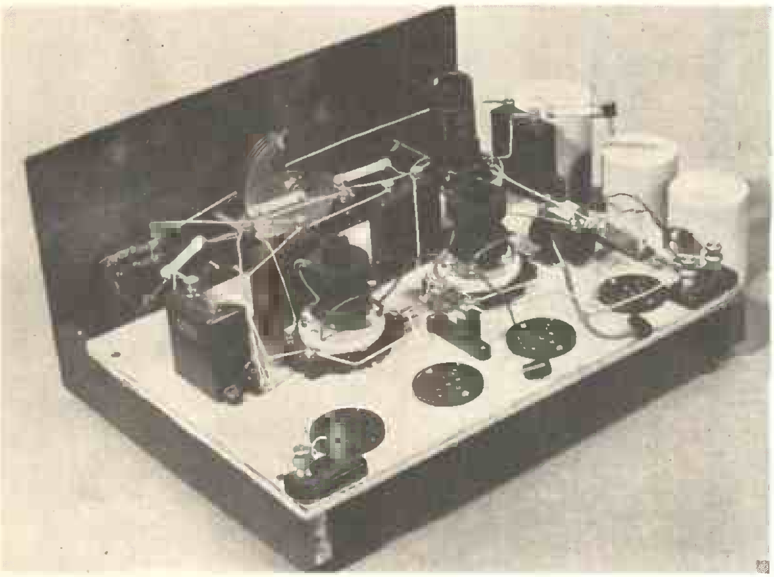


Fig. 4.—HERE CAN BE SEEN MOST OF THE ABOVE-BASEBOARD WIRING.

The Second Detector

Only one valve is used in the intermediate-frequency amplifier, since this is all that is necessary to give an ample degree of amplification. Following the I.F. valve is the " second detector," working on the leaky grid principle. This fulfils the normal function of separating the high- and low-frequency currents so that the latter may be magnified and employed to operate a loud speaker. The last valve is fed through a 7 : 1 ratio transformer ; actually the transformer specified (a Varley " Rectatone ") is intended to be used with a variable resistance for the purpose of tone control, but in this case is employed simply as a normal high-ratio transformer to give a maximum voltage step-up.

Decoupling

All valves are thoroughly decoupled by means of suitable resistances and condensers, with the result that only a single high-tension positive tapping is required. The method of obtaining screening grid voltage for the first two valves is rather unusual, but very convenient and effective. It is seen that the voltage supply is taken from one end of the detector decoupling resistance ; the detector valve and its anode feed resistance form the two "arms" of a fixed potentiometer, so that the voltage obtained from their junction is between a half and two-thirds of the total H.T. voltage applied to the set.

Preventing Wastage of H.T. Current

It should be noticed that a 2-pole battery switch is employed to prevent wastage of H.T. current by the potentiometer when the set is out of use. If a switch of the normal type were used, there would be a continual flow of current from H.T. positive through the potentiometer, valve filaments and accumulator to H.T. negative, and this would naturally cause the high-tension battery to run down much too quickly.

The Components

A list of the necessary components is

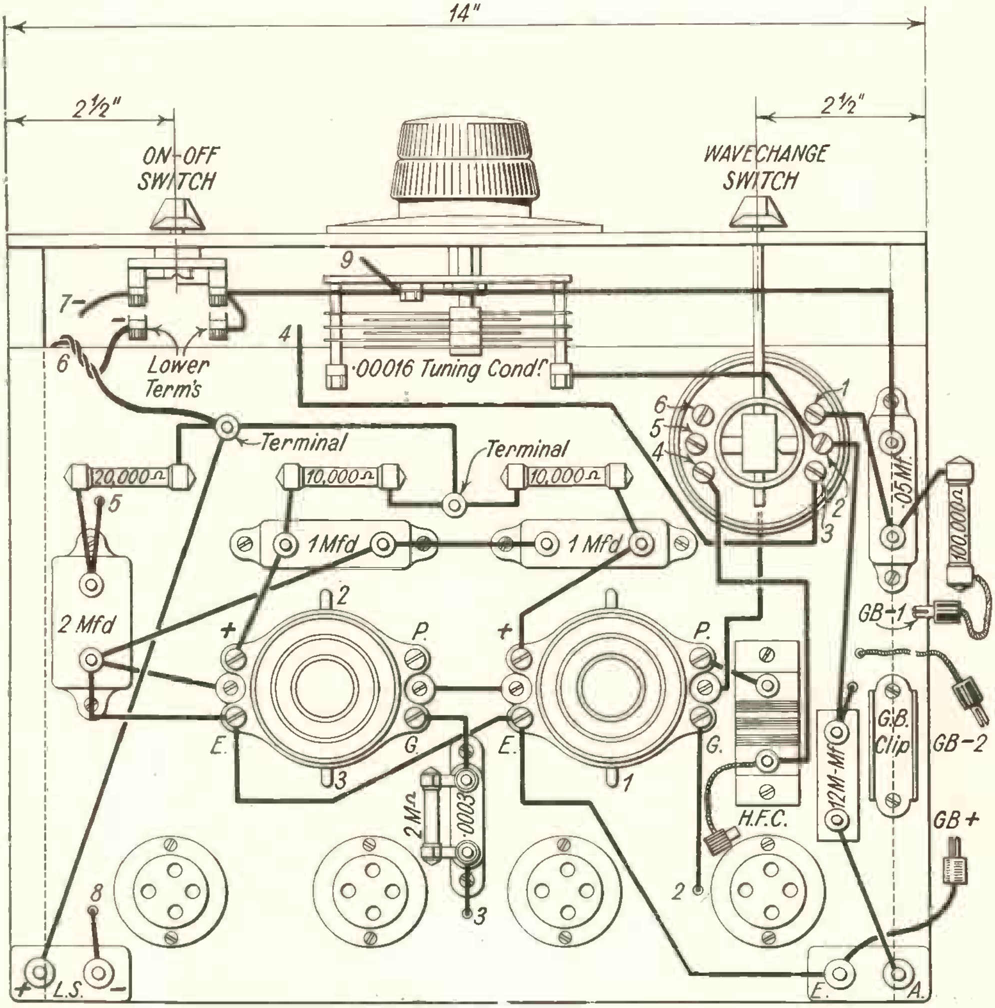


Fig. 5.—Plan of the Above-baseboard Wiring.

given on page 1275, and it should be stressed that all the values, which have been chosen experimentally, should be strictly adhered to. In ordering, notice especially the type of intermediate-frequency transformers specified; they are of a special short-wave pattern and are not the same as those used in a normal superheterodyne intended for broadcast reception. The valve holders may be either 4-pin or 5-pin ones, but in either case connections will only be made to the four "outside" terminals. This point is mentioned because 5-pin holders are sometimes more easily obtainable. To ensure uniformity, all panel components should be ordered with black knobs, since some of them are made in alternative colours.

All the parts can be obtained through any good dealer, so there should be no necessity for ordering specially from the makers.

The Chassis

As a preliminary to the main constructional work, the wooden chassis should be made up as shown in Fig. 3. It consists of a 14 by 7 inches polished plywood panel, a 14 by 10 inches 5-ply baseboard and

* There should be a short length of flex with safety S.G. anode connection attached to terminal P of the Second Intermediate-Frequency Transformer.

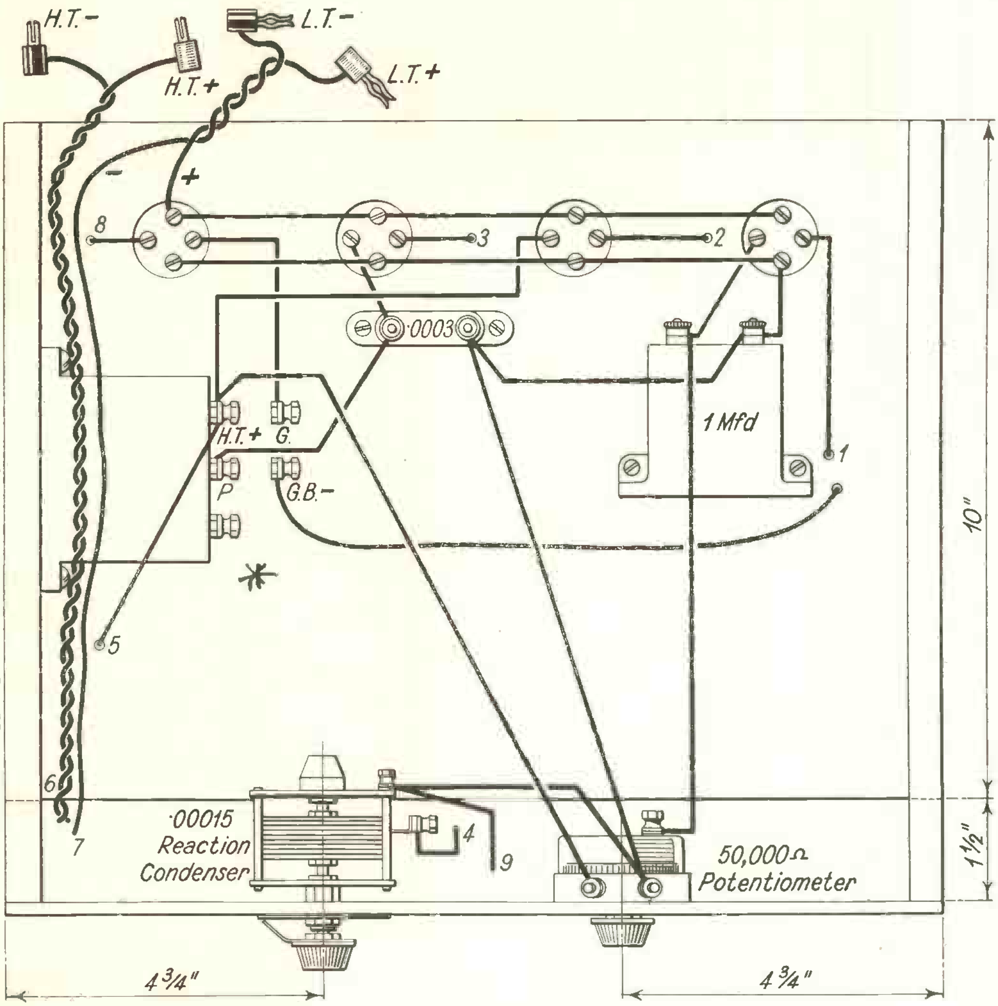


Fig. 6.—Plan of the Under-baseboard Wiring.

two side pieces each measuring $11\frac{1}{2}$ inches long by $1\frac{3}{4}$ inches wide by $\frac{1}{2}$ inch thick. First make four $1\frac{1}{8}$-inch diameter holes in the baseboard to receive the valve holders, and then drill the panel. Before assembling the various parts, the L.F. transformer should be attached to one of the side members, since it will be somewhat inaccessible later. Finally, screw the four members together by means of 1-inch 6's flat-headed brass screws.

Mounting the Components

All the components can now be mounted in the positions indicated in the wiring plans of Figs. 5 and 6, and clearly shown in the various photographs. Start with the tuning coil, taking care that it is directly opposite the hole in the panel through which its switch rod has to pass. Two $1\frac{1}{2}$-inch 6's screws are required for the tuner, and these replace the mounting bolts supplied with it and which are only suitable for an all-metal chassis. The method of attaching the other parts calls for no special comment, since it is perfectly straightforward ; $\frac{1}{2}$-inch 4's round-headed brass screws can be used throughout.

Wiring

This also will easily be followed by studying the wiring plans. All except battery leads are made in "Glazite," of which two coils are quite sufficient. Some wires pass through holes in the baseboard and others are taken through the gap which is left between the panel and front edge of the baseboard. So as to prevent any difficulty or ambiguity, all those wires which cannot be seen in their entirety in either Figs. 5 or 6 are numbered.

Connecting Up the Fixed Resistances

The four fixed resistances and the series aerial condenser are not screwed to the chassis, but are held in position by the wiring alone. The methods of connecting up the fixed resistances require some explanation. One end of each is joined directly to the terminal of another component by means of its own connecting lead, but in the case of the two 10,000-ohm and the 20,000-ohm components a small terminal must be attached to the other end for making connection with the rest of the wiring. The "loose" end of the 100,000-ohm resistance is attached directly to the grid-bias wander plug marked "G.B. – 1."

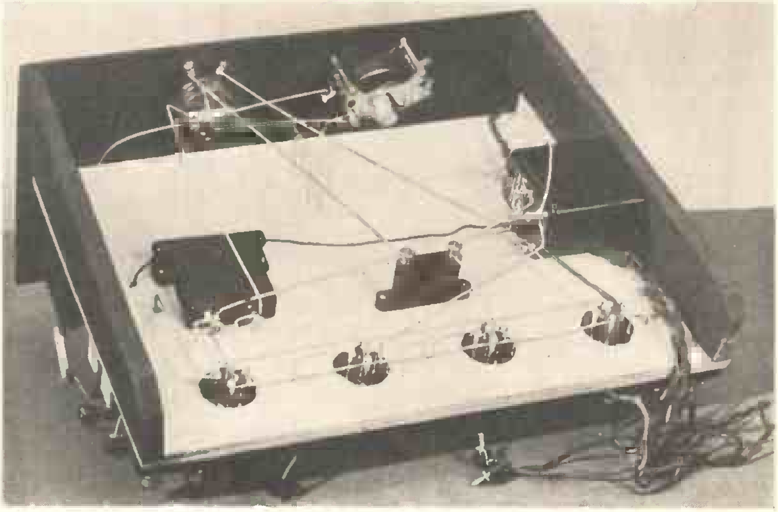


Fig. 7.—The Under-baseboard Wiring.

A Point about Earthing

Another little point which might not be quite clear is that the screening cans of the aerial coil and the two I.F. transformers are earthed. Connection to the can of the aerial coil is made merely by securing the bared end of a length of wire between it and the baseboard. The transformers have small brass earthing tabs immediately below the holding-down screw holes, and connection to these is made by looping a piece of wire round the screws between the baseboard and the tabs. All the latter connecting leads are clearly shown in the wiring plan and photographs.

High- and low-tension battery flexes are secured to the chassis side member by means of two insulated staples to prevent the possibility of their being pulled away from the terminals and so, perhaps, causing a short-circuit.

Testing the Set

After all the wiring has been completed, the set may be connected up to the batteries, aerial, earth and loud speaker. Put plug "G.B. +" into the positive grid-bias battery socket, plug "G.B. – 1" into the $1\frac{1}{2}$-volt socket and "G.B. – 2" into the $4\frac{1}{2}$- or 6-volt socket.

Points about Tuning

Turn the wavechange switch knob to the left or right, so setting the tuner to the lower or higher waveband respectively; adjust the potentiometer knob to a position about "three-quarters on"; rotate the reaction pointer to a scale-reading of "6," and switch on. The set should now be ready for work, and it only remains to tune in with the tuning condenser. This should be revolved *as slowly as possible* by means of the vernier (smaller) knob. You will probably receive a few continuous-wave morse stations first of all, and these will be heard as high-pitched " chirps " ; eventually, however, a telephony station will be received.

Although the first valve is constantly maintained in an oscillating condition, telephony is heard clearly as soon as it is tuned in ; that is, there is no preliminary carrier wave squeak as when using an ordinary type of set. When telephony is heard it should be brought up to maximum strength by careful adjustment, first of the potentiometer and then of the reaction condenser.

Other stations can then be tuned in in the same manner, although once the potentiometer has been set to its best position it will not require any further manipulation except when a very weak signal is being dealt with. As I mentioned before, the first valve must be kept in an oscillating condition, and to ensure this the reaction condenser should occasionally be adjusted—every 20 degrees or so of the tuning condenser will be sufficient. A little more reaction will be required, as the wavelength is increased by turning the tuning dial from 0 to 180 degrees.

Altering the Grid Bias

After the receiver has been set into operation the effect of different grid-bias voltages should be tried ; start by moving plug " G.B. – 2 " one step higher, and then one lower until the optimum position is found. Remember that the H.T. current consumption is reduced as the grid-bias voltage is increased and, therefore, that the highest G.B. voltage with which clear reception is possible should be used. Also bear in mind that the set should be switched off prior to any grid-bias adjustment, for otherwise there will be some danger of damaging the power valve. In all probability there will be no need to change the voltage of plug " G.B. – 1," but it may be tried in the 3-volt socket just to verify this point.

Final Adjustments

Finally, the semi-variable condensers on the two band-pass intermediate-frequency transformers must be tuned to their optimum positions. The capacity of these condensers is varied by moving the two small metal levers which project one on each side of the transformer bases. The correct procedure is as follows : Tune in a " steady " signal, that is, one which is not subject to serious fading ; bring it up to full strength on the reaction condenser and then move the lever marked " 1 " in Fig. 5 until signal strength attains a maximum ; now repeat the process with the lever marked " 2," and finally with lever " 3." As the proximity of the hand whilst making these adjustments is liable to upset tuning, it is best to move the levers by means of a short stick or with a fountain pen.

Sometimes a further slight improvement can be obtained by altering the relative positions of the primary and secondary coils of the band-pass units, but I found it best to set these about an inch apart. If the positions are altered, it will be necessary to make further slight adjustments to the semi-variable condensers.

Once the band-pass units have been accurately tuned they need never be altered again, since the settings will " hold " over the whole tuning range.

Aerial and Earth

It was previously mentioned that the set will operate satisfactorily on any type of aerial, but if alternative ones are available it might be worth while to try them. In general, the highest efficiency is obtained when using an outside aerial some 30 feet long, but quite often a short indoor aerial will prove even better, especially on the lower wavelength range.

The earth lead should be a really good one of low resistance, for this has been found to have a very great effect on the correct functioning of the receiver, and it was noticed that the signals were very much weaker when a long earth lead was in use.

Stations Received

It would be of little value to give details of all the stations that have been heard on this set, and the list would take up a good deal of space. Let it suffice to say that by listening at appropriate hours of the day all the better-known transmissions have been brought in at good loud speaker

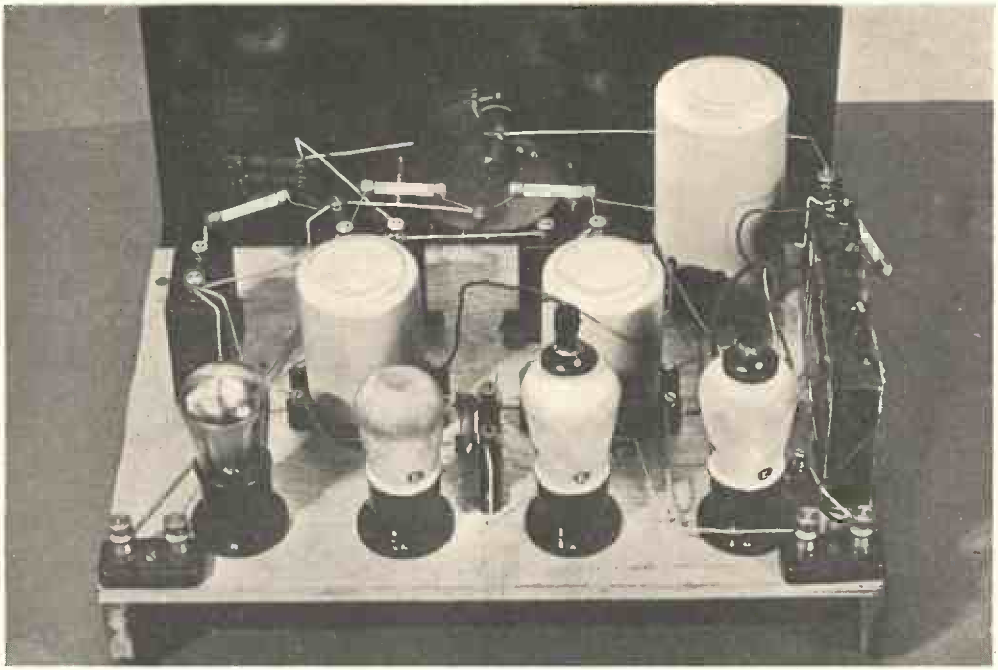


Fig. 8.—Here we see the Back of the Set with the Valves and Coil Covers in Position.

strength ; using phones, scores of lesser important low-power stations have been well received.

With the switch in the 16–32 metre position the 19-metre broadcasters came in towards the bottom of the tuning range, the 25-metre stations round about 80-degree mark and the 30-metre group nearly at the top of the condenser scale. Going over to the higher wavelength range, the 30-metre stations were again heard at the bottom of the condenser, with the many amateurs using the 40-metre band at about 90 degrees, and the 50-metre broadcasting stations between 120 and 150 degrees.

As with any superheterodyne receiver, every station is heard at two settings of the tuning condenser—one 150 kilocycles above and the other 150 kilocycles below the signal frequency ; for example, Moscow on 50 metres comes in at either 141 or 125 on the condenser. It was found in most cases that signal strength was greater at the higher condenser reading.

Having made the set, your best course is to place a list of stations (given in *World Radio*) in front of you and search for them in turns, first on one waveband and then on the other, by setting the condenser to the approximate positions mentioned above.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XXI—MEASURING INSTRUMENTS

IT is amazing how many people profess to be experimenters and yet never use measuring instruments. To experiment without measurements is just like trying to break a speed record without a watch. And, talking about watches, is it not surprising that practically every adult wears a watch and uses it every day, and yet give the same adult an electrical measuring instrument for his wireless set (I suppose by now there are nearly as many wireless receivers in use as there are watches) he won't know what to do with it?

The fun of it is is that an electrical measuring instrument is infinitely less complicated than a watch. As a matter of fact, it is simplicity itself.

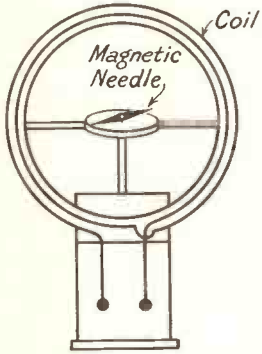


Fig. 1.—WHAT HAPPENS WHEN YOU PLACE A COMPASS NEEDLE INSIDE A COMPARATIVELY LARGE COIL.

If there is no current flowing through the coil, there is no magnetic field around the coil, and the compass will point along the magnetic meridian. As soon as a current is flowing, the coil's magnetic field will come into action and the needle will be pointing to the side.

How Measuring Instruments Help you to Obtain Better Quality from your Set

If you take the trouble to study electrical measuring instruments and fit your receiver with them, you will find that you are not only able to get better quality from your set, but are also able to prevent such things as oscillation. Your set may be oscillating without you being aware of the fact. Given a good circuit, good quality can only be obtained by treating the valves in the right way. This means having right voltages all round. You do not know what these voltages are unless you check them up with the help of a voltmeter.

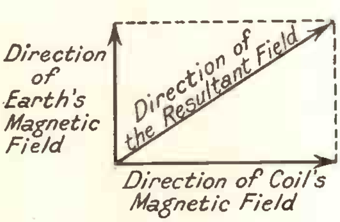


Fig. 2.—DIAGRAM ILLUSTRATING THE INFLUENCE OF TWO FIELDS ACTING SIMULTANEOUSLY.

The diagonal arrow shows the resultant direction of motion when two forces are acting upon an object at right angles.

Simple as they are, electrical instruments are very delicate, and it is essential to understand their construction and to know how to use them. This is what we are concerned with in this article.

The Three Units Involved in Ohm's Law

We know what are the three units involved in Ohm's law. They are the ampere, a unit for measuring the strength of electrical currents; the volt, for measuring E.M.F.; and the ohm, which is a unit of resistance. Now, if we can measure the current strength and we can measure the voltage, we need not trouble to measure resistance, as, once we know the current flowing through and the voltage across a circuit, we can find the resistance of this circuit from Ohm's law, because

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

$$\text{or } R = \frac{E}{I}.$$

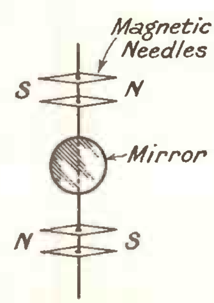


Fig. 3.—DIAGRAM SHOWING PRINCIPLE OF THE ASTATIC MIRROR GALVANOMETER.

Let us see, therefore, how the current and the voltage can be measured.

What a Galvanometer Does

I believe that on many occasions I have mentioned an instrument called a *galvanometer*. A galvanometer, although it finishes with "*meter*," really does not measure anything, unless it is specially designed and specially calibrated to measure something. Normally, it is an indicating instrument. It is used merely to show if there is any current flowing in the circuit. Since the galvanometer is a very useful piece of apparatus for many tests in wireless, let us study it before we devote our attention to ammeters, as the current measuring instruments are called, and to voltmeters.

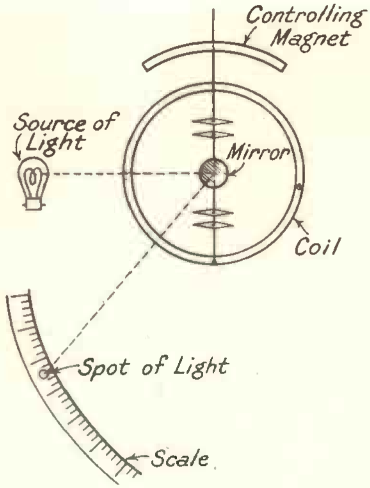


Fig. 4.—The Controlling or Zero Magnet.

The controlling magnet keeps the pointer, which is attached to the rotating spindle, always at zero of the scale.

The Action of a Compass Needle

Let us go back a bit. If you remember, a compass needle will always point with one end towards the magnetic north and with the opposite end towards the magnetic south. What makes it behave in such a way is the fact that a compass needle is a permanent magnet and, being a magnet, it is influenced by the earth's magnetic field. Now, what happens when a compass needle pointing with one end towards the north is placed near a permanent magnet? It will cease pointing north, as now it is being deflected by two magnetic fields, and it will assume some mean position under the influence of the resultant field. The same thing happens if we bring near a compass needle a coil of wire through which an electric current is flowing. There will be a magnetic field around the coil which will influence the compass needle in the same way in which the magnet affected it. Once more the compass needle will not point to the true magnetic north, but to one side of it.

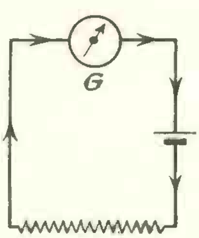


Fig. 5.—Testing a Resistance with a Galvanometer.

If the resistance is continuous, a current will flow and the galvanometer needle will be deflected.

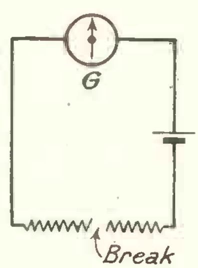


Fig. 6.—Testing a Resistance with a Galvanometer.

If the resistance is broken the galvanometer will fail to deflect.

Try this Experiment

In order to understand how the needle behaves under the influence of the two fields acting upon it simultaneously (the earth's magnetic field and the magnetic field due to the current flowing in the coil), take an oblong piece of cardboard and tie a string near the edge in the middle of the long side and do the same in the middle of the short side. Now, ask a friend to pull one string while you are pulling the other in directions at right angles to each other, and you will find that the piece of cardboard won't move towards your friend, nor will it move towards you, but will choose a direction between the two, as shown in Fig. 2. The diagonal arrow shows the resultant direction of motion when two forces are acting upon an object at right angles.

What Happens when a Compass Needle is placed inside a Comparatively Large Coil

And this is what will happen if you place a compass needle inside a comparatively large coil, as shown in Fig. 1. If there is no current flowing through the coil, there is no magnetic field around the coil and the compass needle will point along the magnetic meridian. As soon as a current is flowing, the coil's magnetic field will come into action and the needle will be pointing to the side.

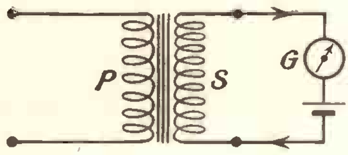


Fig. 7.—TESTING THE WINDINGS OF A TRANSFORMER WITH A GALVANOMETER.

Here we see the windings intact.

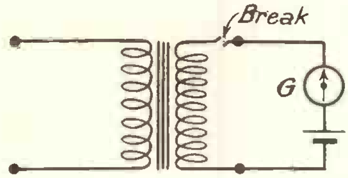


Fig. 8.—TESTING THE WINDINGS OF A TRANSFORMER WITH A GALVANOMETER.

A hidden break is revealed.

What Happens when the Strength of Current Flowing through the Coil is Varied

Now, if you vary the strength of the current flowing through the coil you will vary the strength of the magnetic field around the coil, while the earth's magnetic field remains always the same. In this manner the compass needle will have a different degree of deflection for each strength of current.

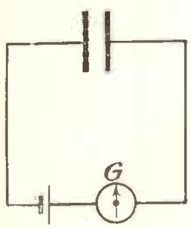


Fig. 9.—TESTING A CONDENSER WITH A GALVANOMETER.

If the condenser is in order there should be no deflection of the instrument.

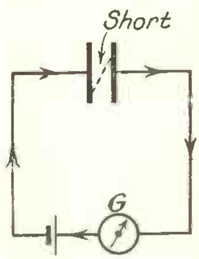


Fig. 10.—TESTING A CONDENSER WITH A GALVANOMETER.

A deflection on the instrument indicates that there is a "short" and the condenser is faulty.

A Simple Galvanometer

Such an arrangement constitutes a simple galvanometer. It will do two things: it will show, by deflection from the true north, that a current is flowing in the coil, and it will also show by the amount of deflection the comparative strength of the current. If we go to the trouble to measure up carefully each deflection for each current strength we can calibrate the instrument to indicate on the scale in amperes. But there are better instruments to do this, so that we shall study the galvanometer only from the point of view of an indicating instrument, giving us a rough comparative idea of the current strength.

How the Influence of the Earth's Magnetic Field is Overcome

The snag with the galvanometer shown in Fig. 1 is that before it can be used the centre compass needle must be set up in the direction of the earth's magnetic field. In order to avoid this and make the instrument independent of the earth magnetic field, four or six magnetic needles are mounted on the rotating spindle or the suspension thread in such a way that while one set of needles has their north poles to the right, the other set has their north to the left. In this manner the tendency of the rotating spindle to rotate under the

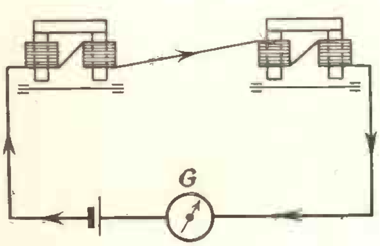


Fig. 11.—TESTING THE CONTINUITY OF THE TWO EAR-PIECES OF HEAD TELEPHONES.

Deflection of galvanometer indicates no break in continuity.

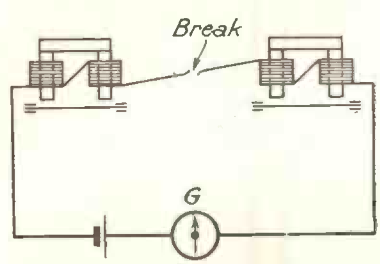


Fig. 12.—TESTING THE CONTINUITY OF THE TWO EAR-PIECES OF HEAD TELEPHONES.

No deflection shows that continuity is broken.

influence of the earth's magnetic field is balanced, the two pulls are in the opposite directions and are equal, and the influence of the earth's magnetic field does not now matter.

Astatic Suspension

Such an arrangement of magnetic needles is called an *astatic suspension*, and the galvanometer is called an astatic galvanometer.

The Controlling or Zero Magnet

In order that the needles remain always in the same position before a current is made to flow through the coil, a controlling or zero magnet is suspended, as shown in Fig. 4. This controlling magnet keeps the pointer, which is attached to the rotating spindle, always at zero of the scale.

A Mirror Galvanometer

For lecturing purposes at schools and colleges, in order to make the deflection of the galvanometer visible to many people at once, a tiny mirror is fixed to the rotating spindle or suspension thread. A beam of light is made to fall upon the mirror, and this beam of light is reflected by the mirror upon a large scale fixed to the wall, the whole being arranged as shown in Fig. 4. Thus our galvanometer now becomes a *mirror galvanometer*.

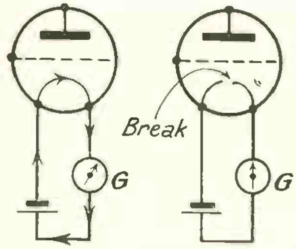


Fig. 13.—How to Use the Galvanometer to Test for the Breakdown of a Valve Filament.

Left, no break; right, filament broken.

In Fig. 1 I have shown a large coil. This coil can be made much smaller so that the whole instrument is much more compact.

There are whole books written upon the subject of galvanometers alone, so that there is no need for me to pursue the subject, but, having given you a rough idea of the principle upon which the instrument works, let us see how we can use it in practice.

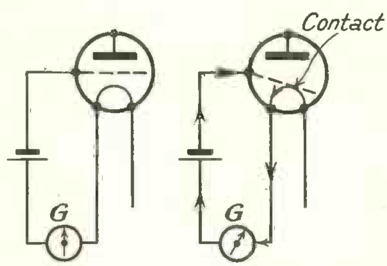


Fig. 14.—How to use the Galvanometer to Test for a Contact between Grid and Filament.

Left, no contact; right, the fault discovered.

How the Galvanometer can be used in Practice

In wireless work and especially in servicing one often comes upon the problem of ascertaining if a certain component is in working order or not. There is a special range of tests which are called continuity tests, and that's where a small galvanometer is very handy. As a rule, the resistance of the galvanometer coil is small, so that it can be worked with a single dry cell, and this is a convenience.

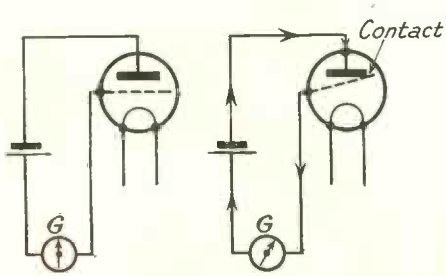


Fig. 15.—How to use the Galvanometer to Test for a Contact between the Grid and the Anode of a Valve.

Left, no contact; right, the fault revealed.

Testing the Continuity of a Resistance

In Fig. 5 you see a resistance under suspicion. The cell and the galvanometer are connected in series with the resistance.

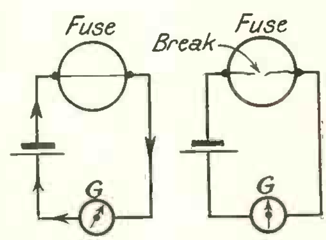


Fig. 16.—How to use the Galvanometer to Test a Fuse in a Mains Receiver.

Left, the fuse intact; right, no deflection on the instrument shows that the fuse has "blown."

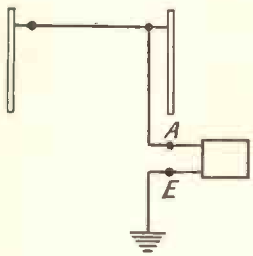


Fig. 17.—How to Test Aerial Insulation.

Here we see a typical aerial arrangement.

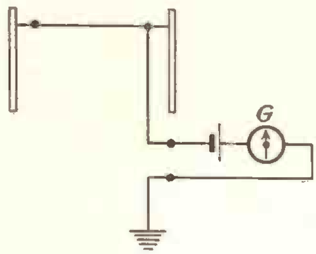


Fig. 18.—How to Test Aerial Insulation.

Here we see how the galvanometer is used to make the test. No deflection on the instrument shows that there is no leakage to earth.

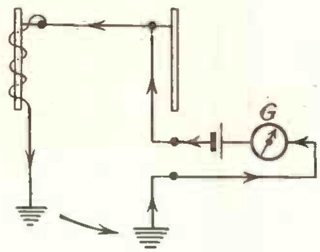


Fig. 19.—How to Test Aerial Insulation.

The deflection of the galvanometer shows that there is a leakage to earth somewhere in the aerial system.

If the resistance is continuous, a current will flow and the galvanometer needle will be deflected. Good enough for our purpose! We know that the resistance is O.K. But should the resistance be broken, and the break invisible to a cursory inspection, the galvanometer will behave as shown in Fig. 6, failing to deflect and thus telling the tale.

Testing the Windings of a Transformer

In Figs. 7 and 8 we have a similar continuity test for one of the windings of a transformer. (Transformer windings have a knack of breaking down in invisible places.)

Testing a Condenser

A condenser can be tested in a similar manner. If the connections are made as shown in Fig. 9 there should be no deflection of the galvanometer pointer, as the dielectric of the condenser " disses " the circuit. But, should the condenser be shorted, or should the insulation break down, the galvanometer will show a deflection, thus indicating that a current is flowing *through* the condenser.

Continuity Test of Head Telephones

Figs. 11 and 12 show a continuity test of head telephones (two earpieces).

Testing for Breakdown of a Valve Filament

Now we come to valves. If a valve does not work, there may be several reasons for it, and some of the reasons may be hidden inside the valve.

A test arranged as shown in Fig. 13 will show if there is a breakdown of the filament. A contact between the grid and the filament is discovered with the help of tests in Fig. 14. If there is a contact between the grid and the anode, it will be discovered by connecting, as shown in Fig. 15.

These two last contact tests may show a breakdown of insulation between the electrodes if not an actual contact, in the case of direct contact the current will be larger and therefore there will be a greater deflection on the galvanometer. Similarly, a fuse under suspicion in a mains receiver may be tested as shown in Fig. 16.

How to Test Aerial Insulation

Aerial insulation, as in Fig. 17, can be tested as in Fig. 18. The test shown in Fig. 19 indicates an earth fault in the aerial, perhaps one

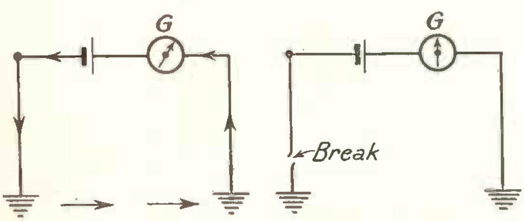


Fig. 20.—Testing for the Efficacy of an Existing Earth.

If there is a break in the earth's lead, this will be discovered.

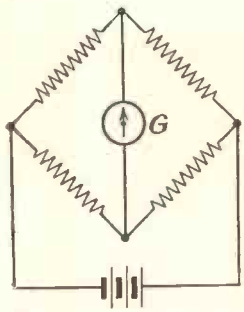


Fig. 21.—How the Galvanometer can be used for Comparative Tests and Wheatstone Bridge Work.

of the insulators shorted. In Fig. 20 we see a test for the efficacy of an existing earth. If there is a break in the earth's lead the test will discover it, as shown.

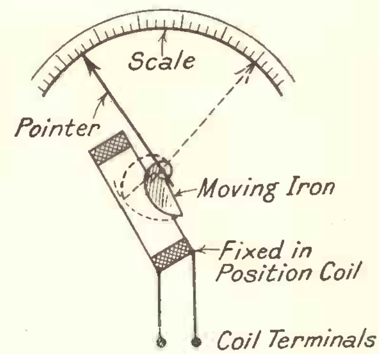


Fig. 22.—Details of the Moving-iron Ammeter.

Using the Galvanometer for Comparative Tests and Wheatstone Bridge Work

The galvanometer is also used for comparative tests and Wheatstone bridge work, as can be seen in Fig. 21. Resistances, inductances and capacities can be thus compared. The effect of two equal capacities, for instance, would be to give the same deflection of the galvanometer during, say, discharge, provided both were charged to the same potential.

CURRENT MEASURING INSTRUMENTS

Now, let us see how the current measuring instruments are constructed. Of these there are three varieties: ammeters for measuring currents in amperes, milliammeters for measuring currents in milliamperes and microammeters for measuring currents in microamperes.

In wireless reception work the ammeter is used for measuring filament current, the milliammeter is used for measuring anode current and the microammeter is used for measuring grid current.

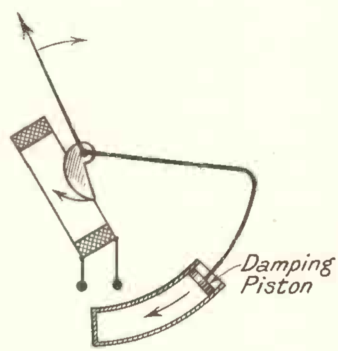


Fig. 23.—Damping Arrangement in a Moving-iron Ammeter.

In order to make the instrument a dead beat one, damping is provided by the compression of air within a cylinder.

Types of Ammeters

Apart from being calibrated to read in different

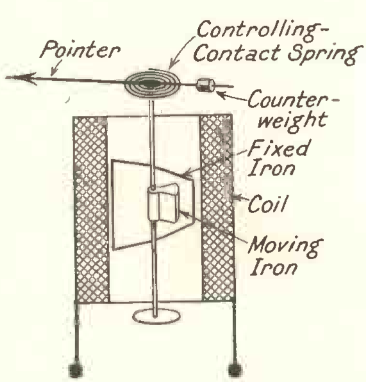


Fig. 24.—Details of the Moving-iron Repulsion Ammeter.

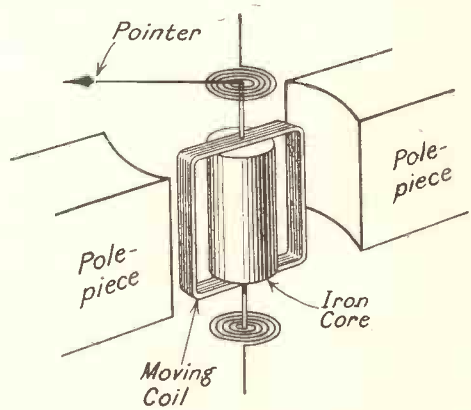


Fig. 25.—Details of the Moving-coil Ammeter.

fractions of an ampere, all instruments of this class work on the same principle. There are two main distinct types of ammeters: the *moving-iron* (attraction or repulsion types) and *moving-coil*. Thus there are two methods of moving the ammeter pointer. There is a third type used specially for A.C. work, the *hot-wire* ammeter which we shall also consider.

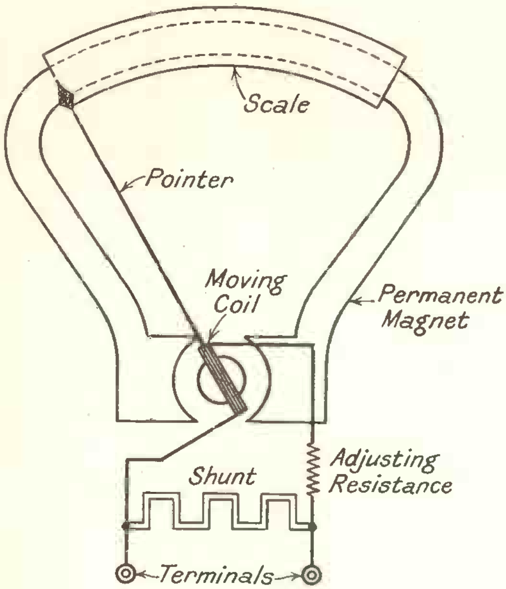


Fig. 26.—How a Shunt is Used in a Moving-coil Ammeter.

When measuring heavy currents, the ammeter is connected in circuit in such a way that not the whole of the current in the circuit is flowing through the coil, but only a known portion of it. This is done by shunts, which are merely slabs of metal of low resistance.

The Moving-iron Ammeter

In the case of the moving-iron attraction type we have a rigidly fixed coil (Fig. 22), close to the opening of which is pivoted eccentrically a shaped piece of iron carrying a pointer. When a current is flowing through the coil a magnetic field is created inside and around the coil, and the moving piece of iron is sucked in inside the coil by magnetic induction. The stronger the current flowing through the coil, the stronger the magnetic field inside the coil and the greater is the movement of the piece of iron. It is possible to establish a relation between the deflection of the pointer and the strength of the current flowing through the coil and thus calibrate the ammeter scale in amperes.

Damping Arrangement

In order to make the instrument a *dead beat* one, *i.e.*, in order to avoid the vibrations of the light pointer while a reading is being taken, a damping arrangement is introduced, one type of which is a piston attached to the pointer, a piston which travels inside a cylinder closed at the opposite end, and the damping is provided by the compression of air within the cylinder (Fig. 23).

The Moving-iron Repulsion Ammeter

The moving-iron repulsion type ammeter is built in a somewhat different way. Here we have a fixed coil inside which is mounted a piece of iron, which is bent to the curvature of the coil for more than a half circle (Fig. 24). This piece of iron is permanently fixed to the inside of the coil and is shaped in such a way that one side of it is much wider than the other (Fig. 24).

The moving iron is represented by a wedge-shaped piece of iron mounted on the centre rotating spindle. When a current is made to flow in the coil and the magnetic field comes into existence inside the coil, both irons become magnetised the same way. The wide side of the fixed iron produces a greater magnetic effect than the narrow side, so that the wide side repels the moving iron towards the narrow side, and the moving iron moves, entraining with it the

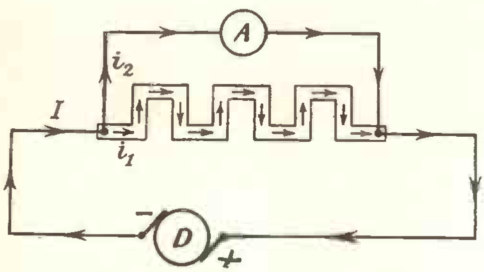


Fig. 27.—Here we see how the Current Divides at the Point of Junction of the Shunt and the Ammeter Terminals.

pointer. The instrument is made dead beat with the help of the controlling spring. Once more the relation between the pointer movement and the strength of the current flowing in the coil is ascertained, and the scale is calibrated accordingly.

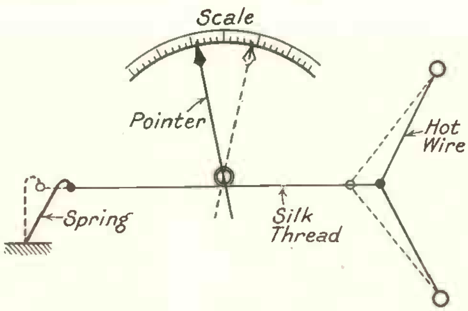


Fig. 28.—Details of the Hot-wire Ammeter.

The Moving-coil Ammeter

The principle of the moving-coil instrument is similar to the above, but in this case we have a constant permanent magnetic field provided by a permanent magnet system, and the moving system is provided by a coil mounted on an iron core, with a current flowing through the coil (Fig. 25). When the current flows it produces a magnetic field around the coil, and this magnetic field causes the coil to be repelled on one side by the permanent magnet and attracted on the other side, and thus made to turn as if it were a piece of iron or another magnet. The intensity of the magnetic field around the coil depends upon the strength of the current flowing through the coil, so that once more we get a relation between the amount of deflection of the pointer and strength of current flowing.

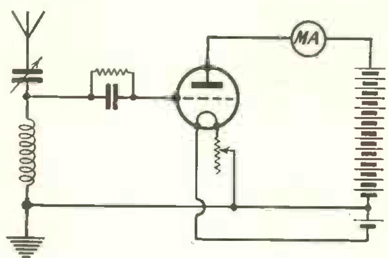


Fig. 29.—The Method of Connecting a Milliammeter in the Anode Circuit.

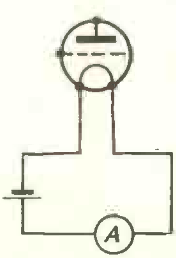


Fig. 30.—How an Ammeter is used to Measure the Strength of Current in the Filament Circuit of a Valve.

Why Shunts are Used

It is obvious that the moving coil in this type of instrument is a delicate affair, and for this reason the ammeter, as a rule, when measuring heavy currents, is connected in circuit in such a way that not the whole of the current in the circuit is flowing through the coil, but only a known portion of it, and it is that portion of it that is measured (Fig. 26). This is achieved with the help of so-called *shunts*, which are merely slabs of metal of necessarily low resistance, as they have a large cross-section.

If you remember, in the case of branched circuits, currents divide themselves in proportion of the resistances of each branch. This can be calculated, or the current in each branch can be measured. Thus, when a shunt is connected across an ammeter, and we know the resistance of the ammeter coil and that of the shunt associated with it, we can calculate the portions of the current flowing through the coil and the shunt, and do this for a number of current strengths. This done, we can deduce the relation between the pointer deflection and the value of part of the current, and therefore of the whole of the current, and calibrate the ammeter accordingly. The way current divides at the point of junction of the shunt and the ammeter terminals is shown in Fig. 27, $I = i_1 + i_2$.

The Hot-wire Ammeter

The hot-wire ammeter is designed as follows. A piece of wire is mounted between two terminals (Fig. 28). The centre of this wire is attached to the end of a silk thread

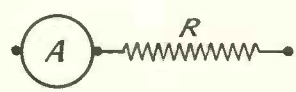


Fig. 31.—The Principle of the Voltmeter.

In order to produce a voltmeter, all we have to do is to connect in series with an ammeter a resistance of known value.

which passes over a pulley to which a pointer is attached, and the other end of the silk thread is attached to a spring which takes up any slack that may occur in the silk thread. When a current is made to pass through the wire, the latter will heat up and increase its length. As soon as this happens, the spring pulls in the slack thus caused in the thread, and the pulley is rotated and with it the pointer. The stronger the current the greater is the heating effect and the greater is the movement of the spring, and, therefore, of the pulley which moves the pointer. Here again we have a direct relation between the strength of the current and the pointer movement.

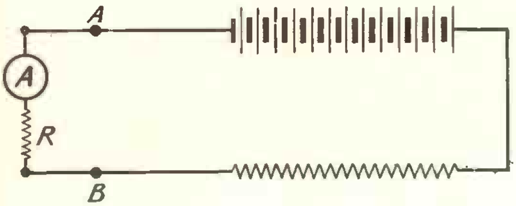


Fig. 32.—How the Voltage across the Points A and B can be Measured.

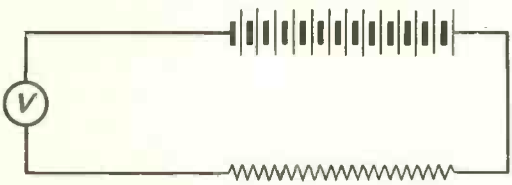


Fig. 33.—How the Voltage is Tested when using a Voltmeter.

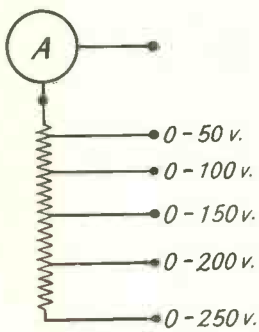


Fig. 34.—This shows how a Multirange Voltmeter is obtained by the use of a Sub-divided Resistance.

What these Different Types are Suitable for

The moving-coil ammeter can be used for direct current work only, as with the reversal of current the direction of the magnetic field would also be reversed, and the pointer would move in the opposite direction.

Thus, with alternating current the pointer would merely wobble about some mean position and fail to give a reading.

The moving-iron instrument, owing to the fact that it works upon the principle of magnetic induction, and there is always an opposite pole induced in the moving iron, resulting in attraction or in repulsion, as in the case of repulsion meter, will work both with direct and alternating currents. Similarly, a hot-wire instrument, since the heating effect is independent of the direction of the current, will work with A.C.

The hot-wire ammeter is specially suitable for measuring high-frequency alternating currents.

The resistance of an ammeter should be as low as possible, as otherwise the ammeter would reduce the strength of the current in the circuit to a very appreciable extent. The golden rule in measurements is that all measuring instruments should disturb the prevailing conditions in the circuit as little as possible.

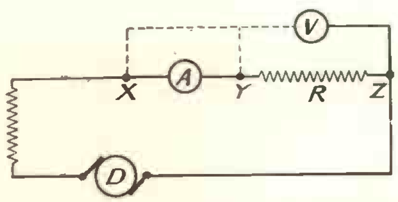


Fig. 35.—Diagram showing the Method of Finding the Value of a Resistance.

How the Ammeter and Milliammeter are Used in a Circuit

An ammeter is used to measure the strength of current in the filament circuit of a valve, and is connected as shown in Fig. 30.

The method of connecting a milliammeter in the anode circuit is shown in Fig. 29.

The Voltmeter

In order to produce a voltmeter all we have to do is to connect in series with

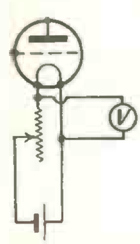


Fig. 36.—The Method of Connecting a Voltmeter across a Valve Filament.

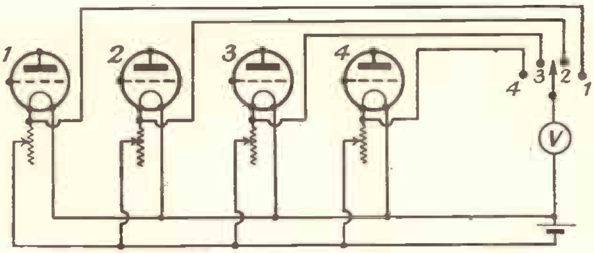


Fig. 37.—HERE WE SEE THE METHOD OF MEASURING THE VOLTAGES ACROSS THE FILAMENTS OF VALVES.

The voltmeter is permanently connected in circuit and connections made *viâ* a stud switch.

an ammeter a resistance of a known value (Fig. 31). Since the resistance of an ammeter itself is very low, for all practical purposes, if an ammeter is connected in series with a known resistance across a circuit, the voltage drop across this resistance will represent the voltage acting across the circuit, as E = RI. Thus, we can measure the voltage across the points A and B, in Fig. 32, as shown. Usually the ammeter and the resistance in series with it are combined into one compact instrument which we know as the voltmeter. Thus the connection in Fig. 32 becomes that in Fig. 33. A multirange voltmeter is obtained by the use of a sub-divided resistance, as shown in Fig. 34.

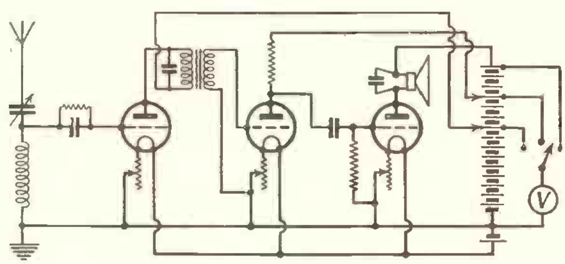


Fig. 38.—HERE WE SEE A SIMILAR METHOD OF MEASURING USED IN THE CASE OF H.T. VOLTAGES.

The resistance of a voltmeter should be as high as possible within the practicable limits.

How the Voltmeter is Used

While the ammeter is always connected in series with the circuit, the current of which we wish to measure, a voltmeter is connected in parallel with the circuit, *i.e.*, across it.

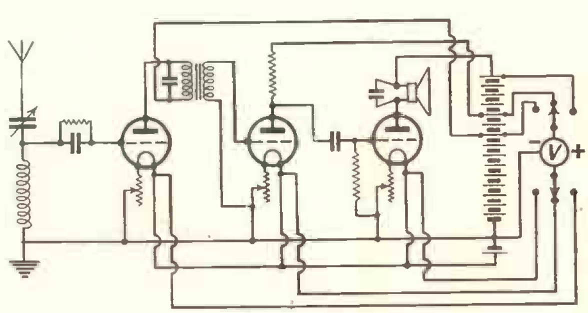


Fig. 39.—A DOUBLE-RANGE VOLTMETER IN USE.

The instrument will measure either H.T. or L.T. voltages.

Finding the Value of a Resistance

And here is a point to consider. In Fig. 35 we have an ammeter in series with the circuit which gives us the strength of the current flowing in the circuit, in amperes. Now, suppose we want to ascertain the value of the resistance R connected between the points Y and Z.

If we know the value of the current flowing through it and we also know the voltage drop across the resistance we can find the value of the resistance itself, as E (which we measure and therefore ascertain the value) is equal I (which the ammeter gives us) multiplied by R (which we want to find). If we connect our voltmeter across the points Y and Z, then this voltmeter will give us a correct reading of the voltage drop across the resistance R.

But the ammeter does not now give the exact current flowing through the resistance (*i.e.*, after the voltmeter has been connected in the circuit), as the current divides at the point Y, part of it flowing through the voltmeter and part of it flowing through the resistance. Thus

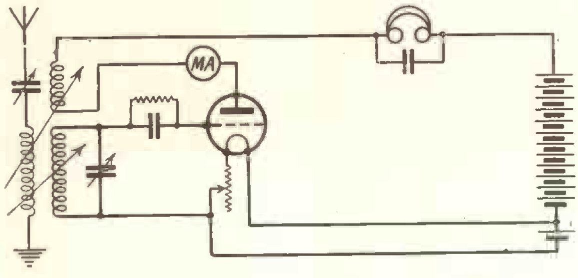


Fig. 40.—How a Milliammeter can be used to detect Oscillation.

While the set behaves itself the needle is steady, but as soon as oscillations set in the needle starts to wobble.

the ammeter indicates the total current in the circuit and not the current which flows through the resistance. It is clear, therefore, that for exact reading we must take into consideration the current taken by the voltmeter and subtract it from the ammeter reading in order to find the current flowing through the resistance.

If, on the other hand, we connect our voltmeter across the points X and Z, our ammeter now gives the exact current flowing through the resistance, but the voltmeter measures the voltage drop not only across the resistance, but also across the ammeter. This means that in order to find the value of the resistance we have to take into consideration the voltage drop across the ammeter, and subtract it from the measured voltage drop in order to arrive at the true voltage drop across the resistance (the voltage drop across the connecting wires is very small, and can be neglected).

It is clear that the greater the resistance of the voltmeter the more negligible is the current taken by it, and, therefore, the difference between the reading of the ammeter and the current flowing through the resistance is made very small and may not matter in practice, when the voltmeter is connected across Y and Z.

Similarly, when the voltmeter is connected across the points X and Z, the smaller the resistance of the ammeter the smaller is the voltage drop across it, and, therefore, the less the difference between the voltmeter reading and the voltage drop across the resistance.

It is obvious that with indifferent instruments, from this point of view, corrections must be made before the correct state of affairs is arrived at.

It is easier to calculate the voltage drop across an ammeter of known resistance, and therefore the voltmeter should be connected across the points X and Z, and the voltage drop across the ammeter should be subtracted from the voltmeter reading.

Connecting a Voltmeter Across a Valve Filament

In Fig. 36 is shown the method of connecting a voltmeter across a valve filament. What we want is the right strength of current flowing in the filament, and for this reason, since the resistance of the filament is constant, we must make sure that we have the right voltage applied across the filament. It is obvious that if the voltmeter is connected across the battery leads it will not give the voltage across the filament, as there is a resistance in circuit as well as the connecting wires. And yet many an amateur planks a pocket voltmeter across his cell, 2 volts? O.K. Steve! Well, it is not O.K.

How to Connect a Voltmeter Permanently in Circuit

Fig. 37 shows a method of measuring the voltages across the filaments of valves, the voltmeter being permanently connected in circuit and connections made *viâ* a stud switch. In Fig. 38 a similar method of measurements is shown in the case of H.T. voltages.

Using a Double Range Voltmeter

In Fig. 39 a double range voltmeter is used and both methods are combined. The voltmeter will measure either the H.T. or L.T. voltages.

How a Milliammeter can be used to Detect Oscillation

When reaction is used it is only fair to other people that every precaution should be taken to avoid oscillations due to forcing of the reaction. It may surprise many to know that their sets may be oscillating and they may not be aware of the fact. A milliammeter connected as shown in Fig. 40 (there is no harm in connecting a milliammeter permanently in circuit) will serve as an insurance against oscillations. While the set behaves itself the milliammeter needle is steady. As soon as oscillations set in the needle starts to wobble. For measuring the anode current flowing in each valve, a milliammeter can be connected in turn in each anode lead between the anode inductance, transformer (primary) or resistance and the positive tapping of the valve in the H.T. battery. The *total* anode current is measured by inserting the ammeter between the negative terminal of the H.T. battery and the filament lead.

As you see, there is nothing very complicated in electrical measuring instruments. This article does not exhaust the list of various electrical instruments, but it covers the most useful ones from the point of view of wireless reception.

In the next article we shall consolidate our acquaintance with the magnetic circuit so that we can discuss intelligently the construction and design of electrical machines.

QUESTIONS AND ANSWERS

What is the Formula used to find the Resistance of a Circuit?

This is found from Ohm's Law, namely,

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}.$$

This formula is, of course, only applicable to direct current, where inductance and capacity do not exert any permanent effect on the current value.

What is the Difference between a Galvanometer and a Voltmeter?

A galvanometer does not really *measure* unless it is specially calibrated. Normally it is an indicating instrument, and is used merely to show if there is any current flowing in the circuit. A voltmeter, however, is definitely a measuring instrument, and enables the actual voltage in a circuit to be measured.

For what Purposes are Ammeters, Milliammeters and Microammeters chiefly used in Wireless Work?

Ammeters are used for measuring filament current. Milliammeters are used for measuring anode current. Microammeters are used chiefly for measuring grid current; they may also be used for measuring incoming aerial signals, provided they are suitable for reading A.C. values.

Name the Three Types of Ammeter Generally Used

(1) The moving-iron (attraction or repulsion types).
(2) The moving-coil.
(3) The hot-wire.

What are these Different Types Suitable for?

The moving-iron type can be used for measuring, both with direct and alternating currents.

The moving-coil can be used for direct current work only.

The hot-wire ammeter is specially suitable for measuring high-frequency alternating currents.

Why should the Resistance of an Ammeter always be as Low as Possible?

Because if the resistance were not low the ammeter would reduce the strength of the current in the circuit to a very appreciable extent. For this reason ammeter shunts are employed to by-pass the greater portion of the current when large currents have to be measured. In this case a different ammeter scale is used.

HOW TO IMPROVE SELECTIVITY

By FRANK PRESTON, F.R.A.

IN numerous parts of this country interference — free reception of even the nearest Regional station —is practically impossible unless the receiver is capable of cutting out the transmissions of a powerful foreigner operating on a nearby wavelength.

The difficulty can invariably be overcome by increasing the number of valves and tuning circuits in the receiver, but this is obviously an expensive and rather wasteful method, so we must try to find some simpler and less costly solution.

In this short article I propose to explain a few of the ways in which the tuning of the average kinds of simple broadcast receivers can be sharpened at a minimum of cost and with the least possible amount of loss in signal strength. I would emphasise at the outset, however, that any increase in selectivity must, in nine cases out of ten, be obtained at the expense of volume and sensitiveness, although if a little care is exercised that "expense" can be kept down to quite low limits.

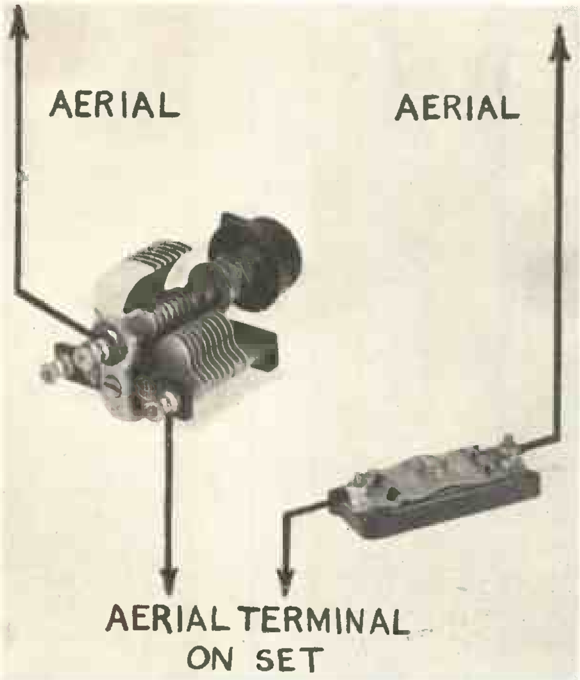


Fig. 1.—THE SIMPLEST WAY OF IMPROVING SELECTIVITY. This is by connecting a variable or semi-variable condenser in series with the aerial lead.

The Aerial and Earth

I do not think it is generally realised that the aerial system may have a tremendous effect on selectivity, and that in many instances a little careful attention to this part of the equipment will produce a distinct improvement. Selectivity is governed principally by the amount of losses in the tuning circuits, and since the most vital of these is connected between the aerial and earth, the latter becomes an important part of it.

The best aerial from the point of view of sharp tuning is one having a maximum length (including lead-in) of no more than 60 feet. The aerial must have the lowest possible capacity to earth and should therefore be kept as far away from earthed objects, such as walls, roofs, trees, etc., as can conveniently be arranged.

Indoor Aerials

An indoor aerial is often as good as an outside one, although in this case care must be taken to have the wire at the greatest practicable distance from walls, especially those having water pipes, gas conduits or electric cables running through them. The same caution must also be observed in taking the lead-in to the set to keep it well away from earthed objects.

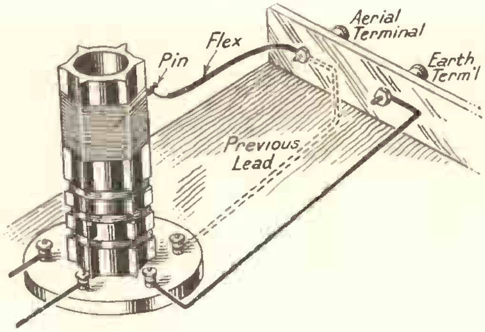


Fig. 2.—A Simple Method of Finding the Best Position for an Aerial Tapping.

The Earth Lead

The earth lead should be as short as possible and make really good contact with the ground. To ensure this the lead must be securely connected either to a cold water pipe, a deeply buried metal plate or a good copper tube driven into damp soil.

When none of these arrangements is possible, one of the recently introduced "chemical" earths will prove of great value. The latter usually consist of a small metal box containing a chemical which has a strong affinity for moisture; the idea is that the chemical attracts moisture from the surrounding soil, and so a good electrical contact between the box and earth is always ensured.

Series Aerial Condenser

Once we know the aerial is right we can consider other methods of increasing selectivity with more confidence. The next most convenient alteration which can be made is that of connecting a small variable or semi-variable condenser between the aerial lead-in and the aerial terminal on the set. A suitable maximum capacity for the condenser is ·0002 mfd., and by proper adjustment the degree of selectivity can be varied over a wide range.

If the variable condenser is mounted on the panel, a means of changing the degree of selectivity to meet any prevailing set of conditions is ready to hand. As the capacity is reduced, tuning becomes sharper and there is a consequent loss in sensitivity, and *vice versâ*.

What the Series Aerial Condenser does

The function of the series aerial condenser is to reduce the "damping" effect of the aerial on the tuned circuit, and thus it produces a similar result to that obtained by shortening the aerial wire. Unfortunately, the condenser lowers the sensitiveness of the aerial system and so causes a certain loss in volume, especially in the case of weaker stations. For this reason, it is always more satisfactory to improve the aerial as much as possible before falling back on the more "artificial" method of increasing selectivity.

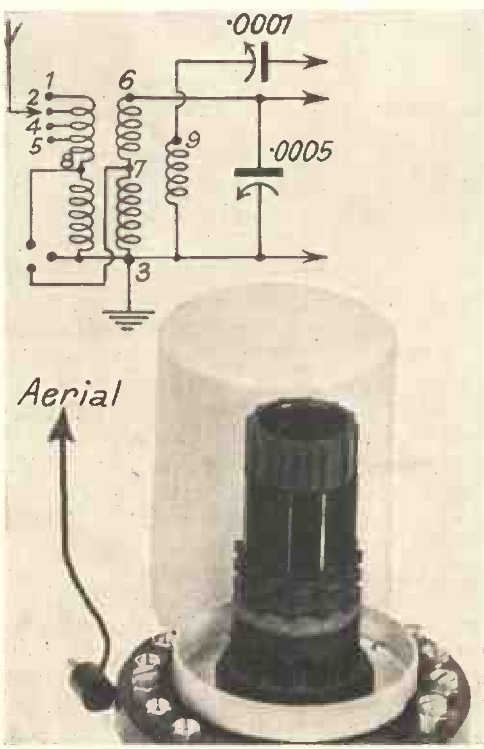


Fig. 3.—A Colvern Type "TD" Dual-range Tuner having a Loose-coupled Winding.

Tapping the Aerial Coil

Aerial damping can also be reduced

by connecting the lead-in to a tapping on the winding of the aerial tuner instead of to one end, as is more usual. If the best tapping point is located with care, the sensitivity of the set is not unusually reduced to any great extent, whilst occasionally (more particularly when the aerial is distinctly poor) results are actually improved.

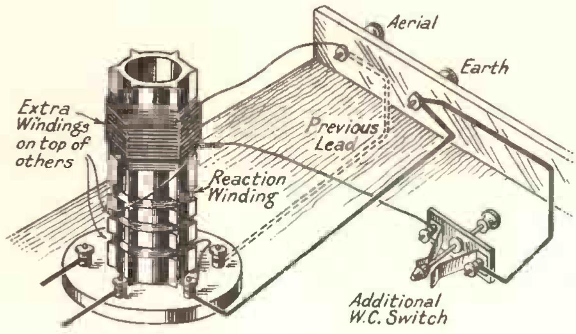


Fig. 4.—METHOD OF IMPROVING SELECTIVITY BY THE USE OF A LOOSE-COUPLED AERIAL WINDING.

Simplest Method of Finding Best Tapping Point

Probably the simplest method of finding the best tapping point when a ready-made tuner is in use is that illustrated in Fig. 2. The wire normally going from the aerial terminal of the set to the tuner is replaced by a short length of flex, to one end of which is attached an ordinary pin; by pushing the pin between the turns at various points the optimum tapping position can be found. Of course, the pin must make proper contact with the wire, and should therefore be pushed through the insulation.

When the best position for the tapping has been determined, a more permanent job can be made by scraping the insulation away from the winding and soldering on a short length of wire, which can be attached to the aerial terminal.

When the tuner is homemade, the most satisfactory method is to rewind the medium-wave coil and take tappings after every ten turns or so. The aerial can then be connected to any tapping at will, and the most suitable one found for use under any circumstances.

Loose-coupled Aerial Coil

Another very excellent way of improving selectivity is to use an aerial tuner having a loose-coupled aerial winding. This latter is placed near to the tuned windings and signals are passed on from the aerial circuit by electro-magnetic induction. By varying the size of the aerial winding, the selectivity of the tuning circuit may be varied; the smaller the winding the less will be the effect of aerial damping and, consequently, the greater the degree of selectivity.

There are one or two tuners on the market which incorporate the principle just referred to, the best known of these being the Colvern type "TD," of which a photograph and circuit diagram are given in Fig. 3. It will be seen that the aerial can be connected to four alternative tappings to obtain different degrees of selectivity; tapping "1" gives the least selective, and "5" the most selective, arrangement.

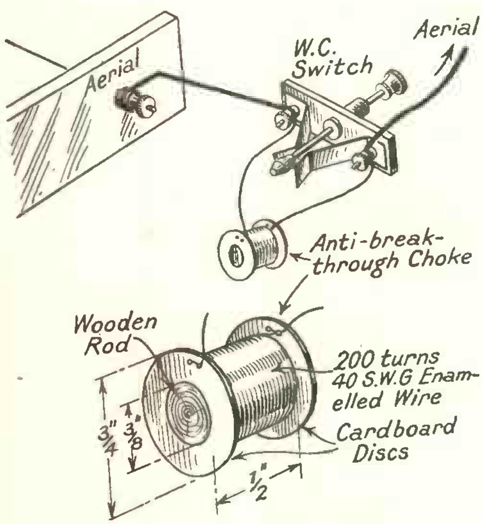


Fig. 5.—THE EASIEST METHOD OF PREVENTING THE "BREAK-THROUGH" OF MEDIUM-WAVE SIGNALS WHEN LISTENING ON LONG WAVES.

Modifying an Existing Tuner

Those who do not wish to go to the

expense of buying a new tuner of the type referred to can modify the existing one in the manner illustrated in Fig. 4. An additional winding of about 25 turns of 26 S.W.G. D.C.C. wire is put on top of the medium-wave coil and one of 75 turns of the same wire (equally divided over the two or three slots) is put over the long-wave coil.

The two new windings are connected in series, and a tapping is taken from their junction to one terminal of an extra wave-change switch. It is essential that the new windings should be wound in the opposite direction to that of the original windings, for otherwise results will be very poor.

Operating the Modified Tuner

The aerial lead is removed from its original terminal and connected to one end of the new winding, of which the other end is joined to earth and to the wavechange switch. The only difference in operating the receiver is that the additional wavechange switch must be used in conjunction with that previously fitted.

In order to obtain the optimum degree of selectivity with the arrangement, it is well to experiment with the number of turns on the smaller winding; a larger number will give less selectivity and more sensitivity, whilst fewer turns will produce the opposite effect. If desired, a higher number of turns, up to 50 or so, could be wound over the medium-wave coil and tappings taken after every tenth, so that the best tapping may be chosen for any particular purpose.

A Band-pass Adaptor

When still greater selectivity is required, it becomes necessary to employ band-pass tuning. The aerial tuner could be replaced by one of the many band-pass coils on the market, or a simple adaptor, which will give the same effect, may be added to the set. In the majority of cases the latter method will be less expensive, since the adaptor can often be made up from parts taken from the junk box.

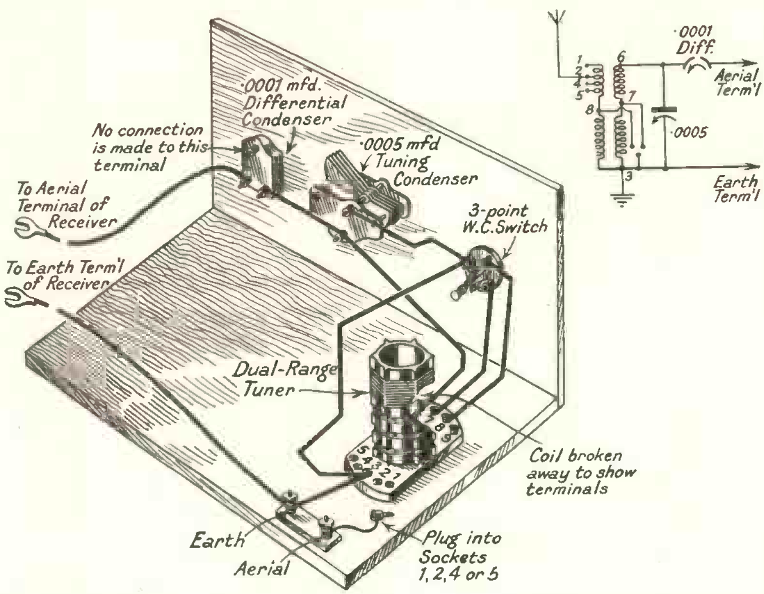


Fig. 6.—Sketch and Circuit Diagram of a Simple Band-pass Adaptor.

Components Required for a Home-made Band-pass Tuner

The only components required are: one aerial tuner (any type); one ·0005-mfd. variable condenser; one ·0001-mfd. differential condenser and a few terminals. The parts are wired up as shown in the sketch and circuit diagram of Fig. 6 (in this case a Colvern type "TD" coil is shown, but any other dual-range tuner would be equally suitable). To use the band-pass adaptor, it is only necessary to transfer the aerial and earth leads from the set to the unit and then to replace them by the two flexible leads which are appropriately marked in the drawing.

Operating the Two Tuning Condensers Simultaneously

The variable condenser on the adaptor must be operated simultaneously with that in the receiver, and in consequence tuning will be a little more difficult at first. It can be simplified a good deal, however, by using a tuner for the adaptor similar to that used for the aerial circuit of the set. Both tuning condensers will then be adjusted to approximately the same dial readings for all wavelengths and can be operated " in step." The degree of selectivity can be varied between wide limits by means of the differential condenser. When the capacity is somewhere near its maximum, tuning will be fairly broad, but by turning the condenser towards minimum capacity the tuning is progressively sharpened.

The band-pass arrangement described above is a very good one, and might successfully be applied to any kind of set which is not already fitted with a band-pass tuner.

Medium-wave Break-through

Although not really coming under the heading of selectivity, the difficulty experienced due to a powerful medium-wave station causing interference when listening on the long waves is a very common one, so it might be advisable to consider it at this juncture.

This " break-through," as it is popularly called, is most easily cured by fitting a special kind of high-frequency choke in series with the aerial lead. The choke must offer a high impedance to medium-wave signals without affecting long waves, and can be made very easily by winding about 200 turns of 40 S.W.G. enamelled wire on a small bobbin about $\frac{3}{8}$ inch in diameter.

A suitable form of construction and the method of connection are shown in Fig. 5. It will be seen that an ordinary 2-point wavechange switch is used to short-circuit the choke when listening on the lower waveband. The switch is essential, because if the choke were left in circuit it would prevent reception of medium-wave stations.

HOW TO CURE "MOTOR-BOATING"

AN annoying source of trouble which occurs more often in mains-driven receivers than in battery receivers is that known as " motor-boating." The following remedies should be tried to cure it :—

(1) Insert a choke-filter output system if this is not already present. If an output transformer is in use, choke-feed it.

(2) Insert a decoupling resistance and condenser in the anode circuit of the detector valve. If the fault still persists, decouple the intermediate L.F. valve, if there is one, in the same way. (Not the last valve, which is the output valve.)

(3) If a tuned anode circuit precedes the detector, make sure that the detector grid-condenser has a capacity not greater than ·0001 mfd. If the trouble still persists, decouple the anode circuit of the H.F. valve immediately preceding the detector.

(4) If bias is taken from the mains, see that the grid bias circuits are decoupled.

(5) Replace ordinary L.F. transformer coupling by parallel-fed transformer.

(6) If all the above remedies fail to cure the trouble, the amplification given by the set at the lowest frequencies may be cut down. In a resistance-coupled (or choke-coupled) amplifier decrease grid condensers and grid leaks. In a parallel-feed transformer amplifier reduce the coupling condenser.

SERVICING

THE CONSOLIDATED RADIO A.C. BAND-PASS THREE

THE following notes relating to the Consolidated Radio A.C. Band-pass Three Receiver will be found useful when servicing this instrument.

Valves

Make sure that these are a good fit in their holders and have not been damaged in transit.

Unselectivity and flat tuning are caused by faulty S.G. valve.

Refusal to oscillate is caused by faulty detector valve.

Fig. 1.—REMOVING OF CHASSIS FROM CABINET. FIRST STAGE.

Remove the three knobs in front of the cabinet by means of an ordinary grub screwdriver.

Should the above fail to locate the trouble, the chassis will have to be removed, which is a simple operation, by removing the three front control knobs (except the escutcheon plate). Then unscrew the two small screws in the metal side pieces in the cabinet and remove the four bolts through the base of the cabinet. The chassis can then be easily tilted out of the cabinet.

Voltage Test

0–500 voltmeter with as high a resist-

Fig. 2.—SECOND STAGE.

Remove the four screws from the base of the cabinet. When carrying out this operation it is advisable to place the instrument face downwards on a baize-covered table with the three spindles just over the edge. For the sake of clearness, however, the set is shown here on its back.

ance as possible should be connected across the Westinghouse rectifier; the reading should be approximately 350 volts. If there is no voltage reading, it may be taken that the transformer secondary is faulty.

Screening Grid of Pentode Valve

A connection should then be made from the positive side of the rectifier to the screening grid of the pentode valve; this reading should be approximately 100 volts; if there is no reading, the loud speaker field is either broken down or disconnected.

Then apply the meter to the negative side of the rectifier and to the earth; a very small voltage reading here should be obtained, approximately 10–15 volts. No voltage reading indicates a broken-down smoothing choke.

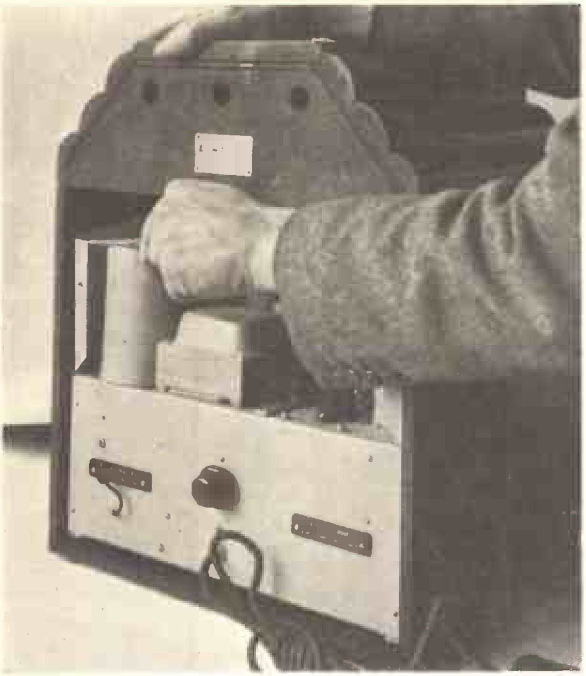


Fig. 3.—THIRD STAGE.

Remove the two screws from the side pieces at the back of the cabinet which hold the speaker.

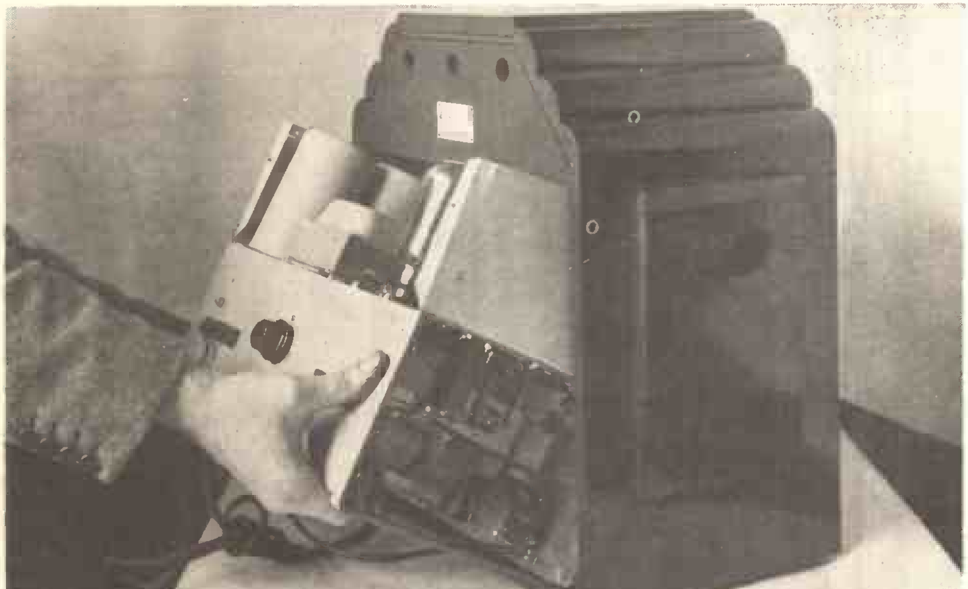


Fig. 4.—FOURTH STAGE.

The chassis may now be withdrawn from the cabinet; pull the chassis slightly towards you, at the same time giving it a tilt towards the front of the cabinet.

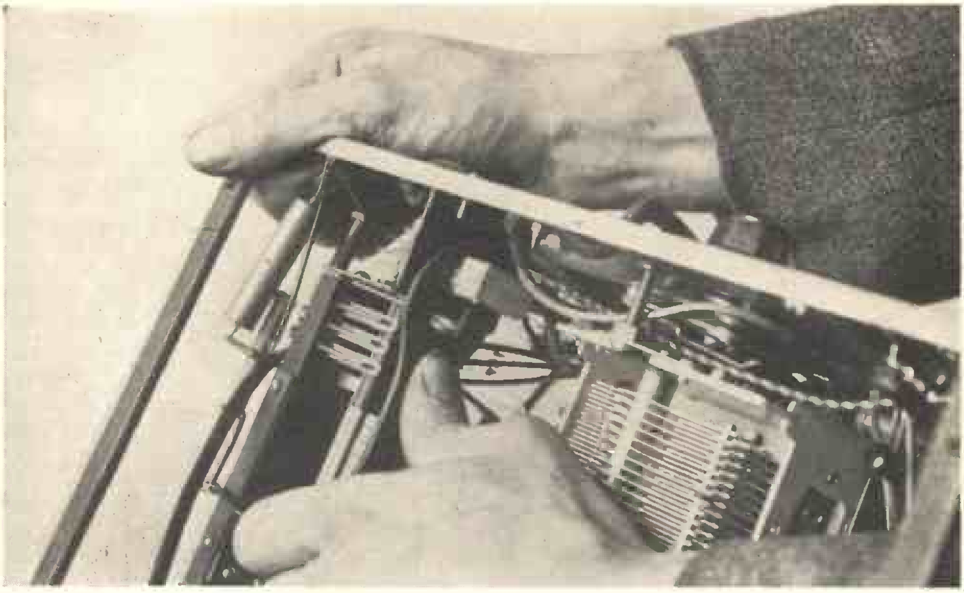


Fig. 5.—How to Adjust the Mains Switch.

It may be found that, after considerable use, this component will require attention. The bottom nut should be loosened and the top one tightened, in order to raise the switch to such a position that the operating arm will throw the " dolly " over to its maximum throw on either side. Care should be taken when making this adjustment that the operating bar does not ground on the bottom of the slot in the " dolly."

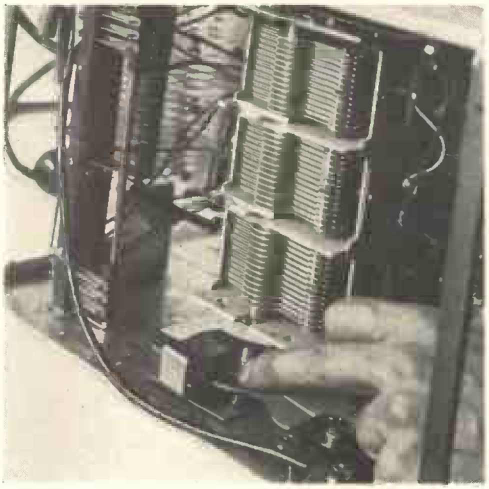


Fig. 6.—Stiff Friction Drive on the Main Tuning Condenser.

This can be easily rectified by smearing the finger with grease and applying a small amount on to the driving rim.

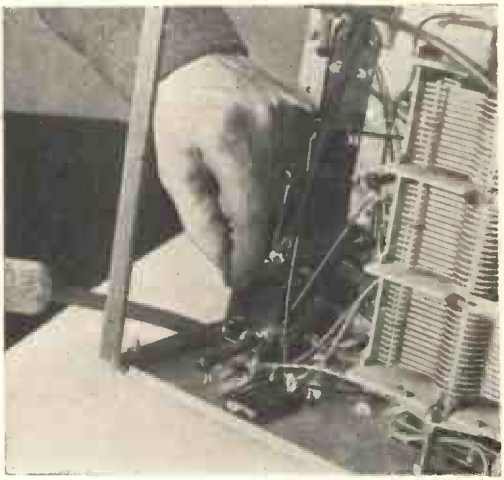


Fig. 7.—Removing the L.F. Transformer.

This is a simple operation and consists merely of unsoldering the four wires going to it and unscrewing the two fixing screws.

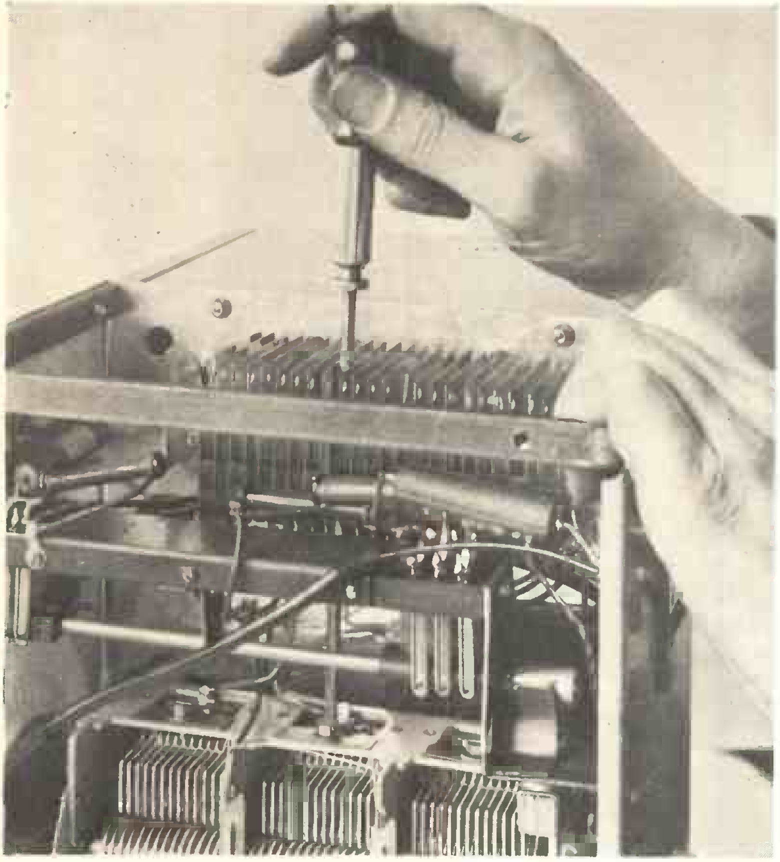


Fig. 8.—Adjustment of the Trimmers on the Three-gang Condenser.

Although these are adjusted when sent out from the works, it may be found after a complete overhaul of the instrument, which has necessitated fitting new valves, that these trimmers may require adjustment to obtain the maximum efficiency. When carrying out this operation, the following is the best method: First of all, adjust the trimmer on the section of the condenser nearest the back of the chassis, so that the readings on the pointer correspond with the correct wavelength on the dial. When carrying out this adjustment it is advisable to adjust when the instrument is just off the point of oscillation. The other two trimmers can then be adjusted so that they are brought into phase with the first trimmer. It will be found that a fairly long-shafted screwdriver will be required and, owing to the fact that it is necessary to pass this shaft through the fins of the rectifier, a piece of systoflex should be slipped over it in order to prevent the possibility of a short.

Other Voltage Tests

Take meter from:

Earth to plate of pentode valve, reading should be 250 volts.

Earth to cathode of pentode valve, reading should be 10 volts.

Earth to plate of detector valve, reading should be 100 volts.

Earth to cathode of detector valve, reading should be 3 volts.

Earth to screening grid of S.G., reading should be 75 volts.

Earth to cathode grid of S.G., reading should be 2 volts.

Earth to plate grid of S.G., reading should be 200 volts.

Incorrect voltage on the cathode of the pentode indicates (*a*) faulty pentode, (*b*) faulty electrolytic condenser (smoothing).

Too high a voltage of the plate of the detector indicates (A) a faulty detector valve; (B) disconnected cathode; (C) a faulty heater circuit.

Too low a voltage indicates disconnection in detector circuit or high-resistance leak from plate to earth.

Faulty cathode voltage indicates broken-down block condenser.

Incorrect S.G. voltages on S.G. valve are due to a faulty block condenser.

Incorrect cathode voltage is due to faulty heater, broken-down block condenser, or faulty S.G. valve.

Incorrect voltage of the plate of the S.G. valve is due to short on anode coil, broken-

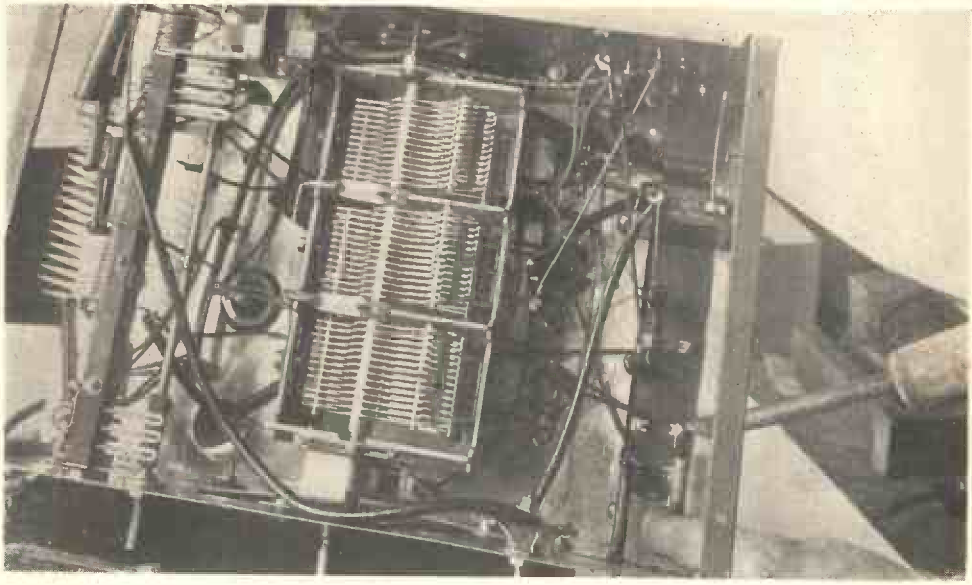


Fig. 9.—Complete View of the Underside of the Chassis.

The operation being carried out is the removal of one of the fixed resistors, a very simple job which needs no explanation.

The values of the various resistances used in this set are given in the table on page 1305, which should be consulted in the event of the replacement of a resistance becoming necessary.

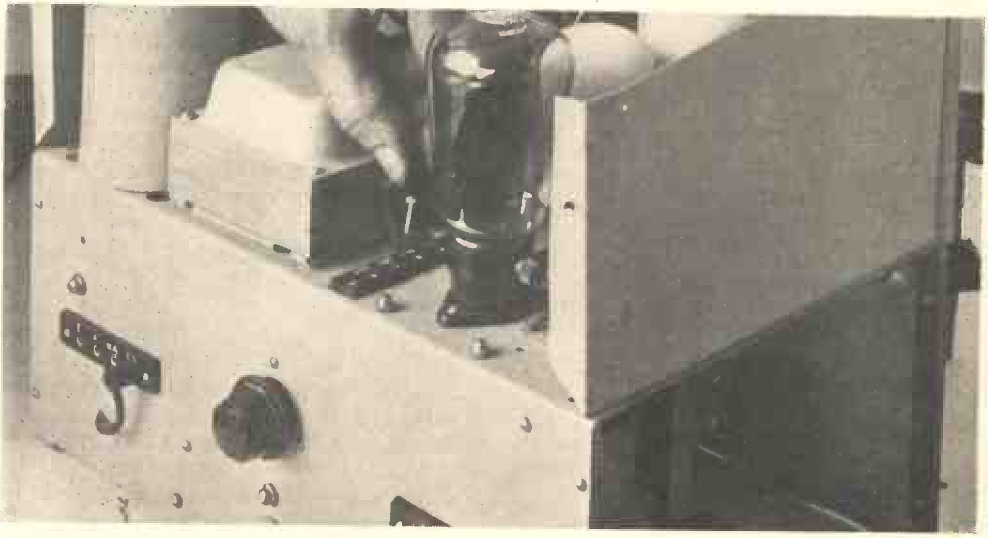


Fig. 10.—The Receiver being Adjusted to the Correct Voltage of Mains Supply.

This is a perfectly simple operation, and consists of inserting the plug in the appropriate socket, as shown in this illustration.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

CONSTRUCTING A METAL CHASSIS

AUTOMATIC GRID BIAS FOR BATTERY SETS

SERVICING HIS MASTER'S VOICE 501 D.C. RECEIVER

1/-

Part 28

IN 32 WEEKLY PARTS

PART 28.

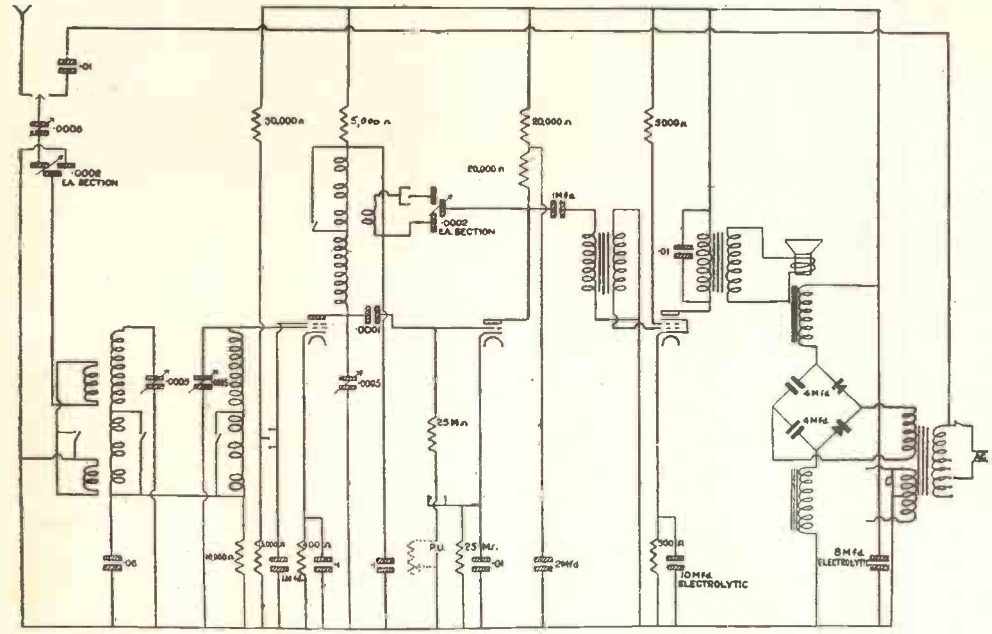


Fig. 11.—THEORETICAL CIRCUIT DIAGRAM OF THE CONSOLIDATED RADIO A.C. BAND-PASS THREE RECEIVER.

down ·01 condenser, faulty valve or heater circuit.

Removing the Chassis of the Consolidated Radio A.C. Band-Pass Three

The first thing to do is to remove the three knobs in front of the cabinet by means of an ordinary grub screwdriver. Then remove the four screws from the base of the cabinet. When doing this it is advisable to place the instrument face downwards on a baize-covered table with the three spindles just over the edge.

Now turn the set up again and remove the two screws from the side pieces at the back of the cabinet which hold the loud speaker in position.

Withdrawing the Chassis

The chassis can now be withdrawn from the cabinet, the best procedure being to stand the instrument in its normal position, and pull the chassis slightly towards you, at the same time giving it a tilt towards the front of the cabinet.

Note the instructions regarding the adjustment of the trimmers of the three-gang condenser which are given under Fig. 8. The shaft of the screwdriver is covered with a piece of systoflex.

Replacement Chart for Resistors.

Ohms.	Body.	Tip.	Dot.
300	Orange	Black	Brown
400	Yellow	Black	Brown
500	Green	Black	Brown
600	Blue	Black	Brown
5,000	Green	Black	Red
10,000	Brown	Black	Orange
15,000	Brown	Green	Orange
20,000	Red	Black	Orange
25,000	Red	Green	Orange
30,000	Orange	Black	Orange
40,000	Yellow	Black	Orange
50,000	Green	Black	Orange
100,000	Brown	Black	Yellow
200,000	Red	Black	Yellow
250,000	Red	Green	Yellow
500,000	Green	Black	Yellow
1 meg.	Brown	Black	Green
2 meg.	Red	Black	Green

Erie resistors are standardised throughout.

The above chart is a guide to the value in the event of replacement being necessary.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION XIII—DETECTOR VALVES—ELECTRO MECHANICS

OF the four methods of detection referred to in Section XII the anode bend method is the most suitable as a starting point for our present discussion because the circuit conditions and the graphical representation of the method are almost exactly as shown at the end of Section XII, where we dealt with the principles of wave distortion resulting in detection.

Typical Anode Bend Detector Circuit

Fig. 1 shows a typical anode bend detector circuit. The valve is biassed so that its operating point is at the lower bend of the grid voltage—anode current curve. The signal voltage is induced into the tuned circuit, comprising L and C, and the voltage across the circuit produces a variation in grid potential. The positive half cycles of the signal result in an increase in anode current, but the negative half cycles produce scarcely any change at all in anode current, for, since the operating point of the valve is at the lower bend of the characteristic, wave distortion occurs and the negative half cycles of the signal are almost completely suppressed, as illustrated by Fig. 10 of Section XII: the positive half cycles of the signal produce a mean *increase* in anode current. When an unmodulated carrier is being received the increase is constant, but when the carrier is modulated the increase varies according to the variation of the maximum carrier-amplitude—*i.e.*, according to the modulation percentage.

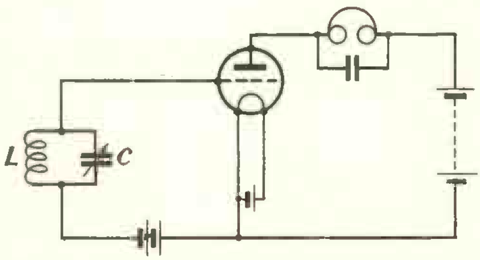


Fig. 1.—A Typical Anode Bend Detector Circuit.

Two Important Cases

During transfer from the grid to the anode circuit the signal is amplified as well as rectified, and, as has already been seen, the extent of the amplification depends on the slope, or mutual conductance, of the valve under the operating conditions. Let us consider two important cases of anode bend rectification: (1) when the input signal is small, and (2) when the input signal is large.

Wave Distortion

Fig. 2 shows the lower bend of a typical characteristic curve on an enlarged scale. Input and output signal curves are also shown for the case of an unmodulated sine wave carrier of small amplitude: the actual grid voltage variation is of the order of a fraction of a volt. It will be seen that, due to the curvature of the characteristic, wave distortion has occurred. For convenience of comparison the dotted curve shows the output signal which would have resulted from a straight characteristic, also shown by a dotted line.

Instantaneous Amplitudes

It is clear that, in addition to a partial suppression of the negative half cycles of the wave, the *instantaneous amplitudes* of the positive half cycles of the output signal have been changed slightly. This is a form of distortion which is undesirable, and it is due to the introduction of frequencies which were not present in the original signal. The frequencies introduced are HARMONICS, or OVERTONES—the former term is used mainly by mathematicians, physicists, and engineers, and the latter chiefly by the musician. So far as an unmodulated carrier is concerned the distortion is unimportant. In the case of the modulated wave, however, the distortion represents the introduction of harmonics of the speech and music frequences from the studio.

Fundamental or First Harmonic

Suppose that middle C is played in the studio. The pure note (called the FUNDAMENTAL or sometimes the FIRST HARMONIC) has a frequency of 256 cycles per second. Its harmonics have frequencies of 2 × 256, 3 × 256, and so on, and are called the second, third, and so on, harmonics. The notes from musical instruments are not pure tones but are a mixture of fudamental and harmonics. The exact mixture—that is to say, the ratio of the maximum amplitudes of the fundamental and of the various harmonics—determines the CHARACTER of the note. The character of a note assists us to distinguish between notes of the same pitch but produced by different instruments.

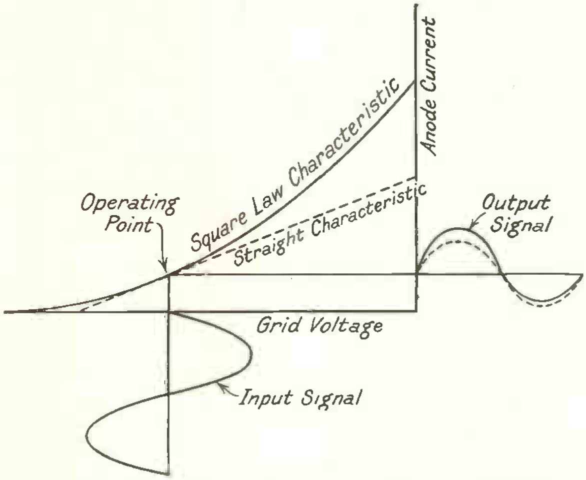


Fig. 2.—THE LOWER BEND OF A TYPICAL VALVE CHARACTERISTIC CURVE.

Harmonic Distortion

The amount of harmonic distortion introduced by the anode bend rectifier when the signal is small is quite considerable. For the case of a rectifier in which the output signal is proportional to the square of the input signal amplitude, which is approximately the case of anode bend detection at small signal amplitudes and is called the case of SQUARE LAW RECTIFICATION, the amplitude of the second harmonic is from 15 to 25 per cent. of the amplitude of the fundamental tone. The actual ratio of the second harmonic to fundamental depends on what is known as the MODULATION PERCENTAGE of the transmitter. Most broadcasting stations have a modulation percentage of between 60 and 100 per cent., the latter figure being the maximum obtainable figure.

Conditions when Input Signal is Large

In Fig. 3 are shown the conditions when the input signal is large. One complete cycle of a sine wave carrier is shown. P is the operating point and Q is the point corresponding to the maximum carrier amplitude. The signal is sufficiently great to take Q on to the straight portion of the characteristic. On the negative half cycles of the signal the grid potential is brought to the point R. Now, when the carrier is modulated the envelope of the modulated wave—which is the curve of interest to us from the point of view of detection—is shown as two curves (see (*a*) and (*b*) of Fig. 6, Section XII) about the grid potentials at Q and R. Since Q is on the straight portion of the characteristic a mean variation about Q results in an undistorted signal in the anode circuit. A mean variation about R does not introduce a component into the anode circuit provided that the variation is small—*i.e.*, provided that the modulation percentage is small. For large modulation percentages the mean variation about R introduces very slight distortion. Also, for a large modulation percentage, the mean variation about Q results in the introduction of harmonics of the modulation frequencies, but the amplitudes are small in comparison with the amplitudes of the fundamentals. The total amount of distortion introduced in this case is extremely small, however, and hence the anode bend method of detection is to be recommended when good quality reproduction is required from a large signal voltage.

The Anode Bend Rectifier should be followed by a Transformer Coupling

The anode bend method is not highly sensitive, and it is advisable to follow an anode bend rectifier by a transformer coupling to the first audio-frequency amplifier stage to compensate for this deficiency in some measure. It is important to note that no grid current flows in the case of anode bend detection, and hence the effect of the valve on the selectivity and on the sharpness of tuning of the tuned circuit is smaller than in the cases of grid rectification which we shall discuss now, and where the existence of grid current is a necessary condition for rectification.

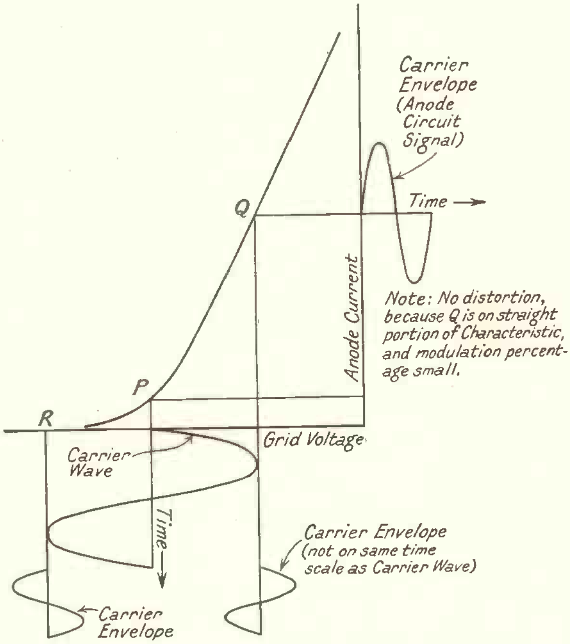


Fig. 3.—HERE WE SEE THE CONDITIONS WHEN THE INPUT SIGNAL IS LARGE.

One complete cycle of a sine wave carrier is shown.

Grid Rectification

In the cases of both leaky grid and power grid rectification the existence of grid current is a fundamental and necessary condition for rectification. It must be understood that in these two systems, rectification occurs in the grid circuit—*i.e.*, before the signal is transferred to the anode circuit.

What Rectification Implies

Now, rectification implies, as we have already seen, the production of a secondary signal from the primary, or input, signal, the secondary signal corresponding to the envelope of the primary signal. In the case of anode rectification the audio-frequency variations of the anode current constitute the secondary signal. In the case of grid rectification the secondary signal as well as the primary signal exists in the grid circuit. If we merely take the circuit of Fig. 4 and bias the valve so that grid current flows we shall not obtain grid rectification. We may obtain rectification in some form or other, but we shall not concern ourselves with what happens under these conditions. For grid rectification a grid lead and grid condenser must be employed, connected as shown in Fig. 4 at R and C.

Analysis of a Grid Circuit

Before we can proceed further with our explanation we must subject the grid leak and condenser circuit of Fig. 4 to careful analysis. The D.C. resistance of the tuning coil L_1 is negligible in comparison with the resistance of the grid leak R. It will be seen that R, L_1, and the valve filament (also of resistance negligible in comparison with R) are in parallel with the grid condenser C. Approximately,

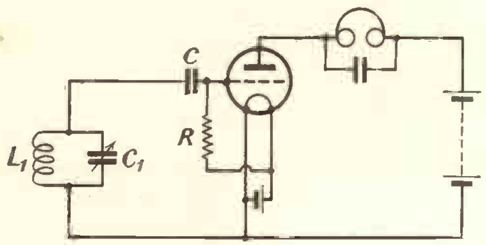


Fig. 4.—CIRCUIT FOR GRID RECTIFICATION.

therefore, we can say that R is in parallel with C, for the effects of L_1 and the valve filament are negligible. Consider what would happen if C were given a charge. Clearly, the charge would slowly leak away through R until it was dissipated. The charge would become a current through R and the current would raise the temperature of R slightly; the energy of the charge would thus become converted into heat.

Theoretically, the charge never completely leaks away, but in practice a stage is reached when the charge remaining is sufficiently small to be immeasurable. When this stage is reached we say that the charge has completely leaked away. The time taken for this to occur depends on the values of R and C. The larger R and C are, the longer the charge takes to leak away; also, the longer the charge takes to reach a value which is a given fraction of its initial value.

Reception of an Unmodulated Carrier Wave

What has this to do with grid rectification? Consider first the case of the reception of an unmodulated carrier wave. When the signal is being received it causes

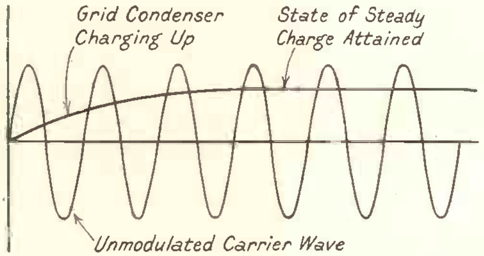


Fig. 6.—SHOWING HOW THE GRID CONDENSER SLOWLY CHARGES UP TO A STEADY POTENTIAL AS THE INPUT SIGNAL ALTERNATES.

the condenser C (Fig. 4) to become charged; the charge steadily leaks away through R and the current through R produces a P.D. across the ends of R. This P.D. is applied to the grid of the valve, and hence the presence of the signal causes the grid potential to change by an amount which depends on (1) the amount of charge leaking away through R, and (2) the resistance of R. We should expect that as the signal alternates the charge on C alternates; when p is positive with respect to q (see Fig. 5) the condenser C becomes charged as shown at (*a*), and, when the alternation occurs, C reverses its charge, as shown at (*b*), the charge leaking away as the alternation occurs.

This is not so, however, for the values of R *and* C *are so chosen that the charge due to one half cycle does not have time to leak*

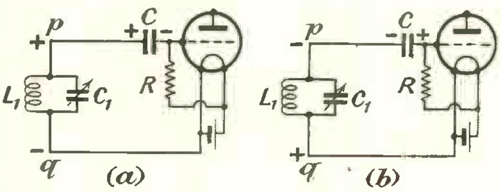


Fig. 5.—SHOWING HOW, WHEN THE SIGNAL ALTERNATES, THE CHARGE ON THE CONDENSER ALTERNATES.

away as the alternation occurs. What happens is that one set of half cycles of the signal have the effect of charging up C to a steady potential; the other half cycles have practically no effect, and it can be shown that, due to the fact that grid current is flowing in the no-signal condition, it is the positive half cycles of the signal which charge up C, leaving a steady negative potential on the grid as shown by Fig. 5 (*a*).

Fig. 6 shows how the grid condenser slowly charges up to a steady potential as the input signal alternates. After the first few complete cycles the grid potential remains quite steady.

Note, that, in the case of grid rectification, the mean grid potential is more negative when a signal is being received than in the no-signal condition, and hence the anode current *decreases* when a signal is applied to the grid. In the case of the unmodulated signal the decrease is constant, but when the carrier is modulated the decrease varies with the modulation—*cf.* the case of anode rectification.

Reception of a Modulated Wave

In the case of the modulated wave—as implied by the preceding note—the charge on the grid condenser varies with the audio-frequency maximum amplitude variations of the carrier wave. This is because the values of R and C are a compromise — they are also chosen so that the charge on C *can* leak away through R during the time occupied by an *audio*-frequency alternation, and thus the charge on C is able to follow audio-frequency variations in the carrier maximum amplitude. Hence the grid potential varies at audio frequencies, the variations corresponding to the envelope of the positive half cycles of the carrier wave.

Harmonics of the Modulation

So far, it would appear, the grid potential variations are an exact copy of the modulation, but unfortunately a second effect arises which introduces distortion. The variations of grid potential cause variations of grid current through the valve, and the current variations do not correspond exactly to the grid potential variations, the resultant effect being the introduction of harmonics of the modulation into the grid circuit. Thus the nett voltage fluctuations at the grid comprise variations corresponding to (1) speech and music from the studio, and (2) harmonics of this speech and music.

A Typical Grid Circuit Rectifier

In Fig. 7 are shown the grid current and the anode current curves for a typical grid circuit rectifier. P_1 is the operating point on the *grid current* curve, and P_2 is the operating point on the *anode current* curve, and it will be observed that P_2 lies on the straight portion of the characteristic. We have seen that an audio-frequency signal is available at the grid of the valve when rectification has taken place. This signal is now transferred into the anode circuit as described in Section XII, and since P_2 is on the straight portion of the anode-current curve the transfer is effected without wave distortion, and the signal is amplified. That is to say, the grid circuit rectifier actually performs two functions (*a*) rectification, and (*b*) subsequent amplification of the modulation component of the original input signal.

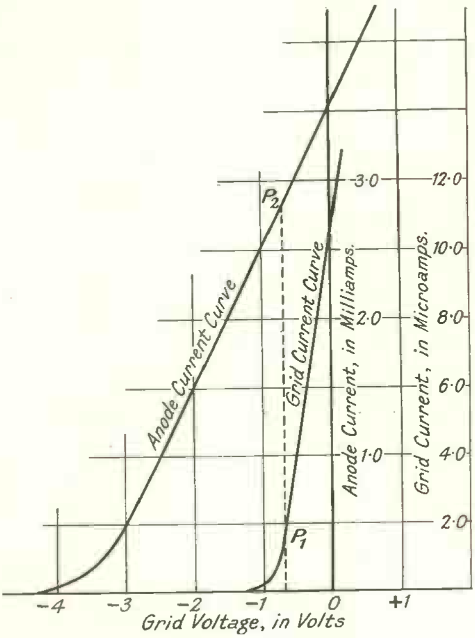


Fig. 7.—Grid Current and Anode Current Curves for a Typical Grid Circuit Rectifier.

Difference between Leaky Grid and Power Grid

We must now distinguish between the leaky grid and the power grid systems of rectification.

(1) Leaky grid rectification occurs when the input signal is small. Harmonic distortion is introduced and the extent of the distortion is of the same order as that experienced with anode bend rectification at small signal voltages. The usual grid leak and grid condenser values are 1 to 5 megohms, and ·0001 to ·0005 mfd., respectively. The system is highly sensitive and a good order of efficiency can be obtained.

(2) Power grid rectification occurs at large signal voltages, and it can be shown that the amount of harmonic distortion is extremely small, especially when the modulation percentage does not exceed some 80 per cent. The small amount of distortion experienced is not due, however, as is often erroneously stated, to the fact that the powerful signal takes the operating point onto the straight portion of the grid current curve, but is due to the fact that grid current does not flow during the whole time that the signal is being received, but only during heavy and peak modulation periods. Grid current flows, of course, in the no-signal condition, and is a necessary condition for rectification to occur, as was emphasised earlier. Grid leak and condenser values are ·25 to ·5 megohms and ·0001 mfd., respectively. A power grid detector circuit—*i.e.*, a circuit employing the values of R and C necessary for power grid rectification—degenerates into a leaky grid detector circuit at small signal voltages.

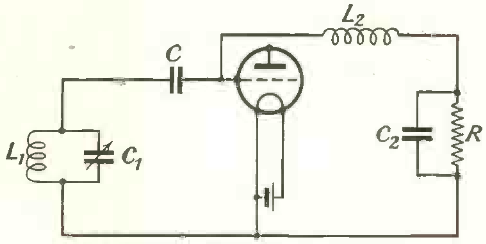


Fig. 8.—A Simple Diode Circuit.

The Diode Rectifier

The diode rectifier is similar in action to the grid rectifier, but the action is limited to that of rectification only. The audio-frequency amplification which occurs between the grid and anode circuits in the case of the grid rectifier is obtained with a separate amplifying stage in the case of the diode.

Simple Diode Circuit

Fig. 8 shows a simple diode circuit; C corresponds to the grid condenser and R to the grid leak of the grid rectifier, C usually being called the blocking condenser and R the output resistance. An H.F. choke, L_2, is inserted in the output circuit to keep H.F. energy from R, which also forms the input circuit of the audio-frequency amplifying stage which follows.

When a signal is being received C becomes charged up, as in the case of the grid rectifier, the positive half cycles of the wave producing a steady charge on C. The values of C and R are chosen, as previously, so that C cannot discharge through R as the alternation of the carrier signal occurs, but the charge on C can vary at audio frequencies.

Thus, modulation of the carrier wave produces a variation of the charge of C. The valve employed is of the type in which grid current exists when the grid is connected to the filament, and hence the varying charge on C—that is to say, the varying potential at the grid—sets up a varying current through R, and hence a varying P.D. across R. This varying P.D., which corresponds to the modulation of the carrier, is applied to the grid of the following valve, which is an audio-frequency amplifier. The condenser C_2 acts as a by-pass condenser for any stray H.F. energy that has penetrated past the H.F. choke L_2.

The diode rectifier can be shown to be highly efficient and to give practically distortionless reproduction for both small and large modulation percentages. The damping effect on the tuned circuit, L_1C_1, is considerably less than in the case of the grid rectifier, and the effective load resistance is of the same order as the resistance of the output resistance R.

The Blocking Condenser

In the cases of both grid and diode rectifiers it is important to note that the blocking condenser C, forms an alternative path for the audio frequencies. In the case of the lower frequencies the condenser impedance is sufficiently large to make the effect negligible, but at high audio-frequencies this may result in slight attenuation. The use of as small a capacity as is found satisfactory from the point of view of rectification is always to be recommended for this reason.

There are a great many problems connected with rectification and with which it is quite impossible to deal in the short space now available. The case of the superheterodyne receiver differs from that of the ordinary receiver in so far as the superheterodyne instrument incorporates two rectifiers, and between them there are tuned circuits and amplifiers which act as filters, filtering only some of the signal components from the first rectifier through to the second rectifier.

When interference is being experienced from an unwanted station, the effect of the interference on the reproduction depends partly on the type of rectifier employed. That is to say, the problem of selectivity is not concerned solely with the questions of the aerial and tuning systems employed in the receiver, but also with the type of rectifier employed, and we shall discuss this in a later article in this series.

SOME ELECTRO-MECHANICAL CONSIDERATIONS

THERE are several electro-mechanical devices employed in sound-reproducing equipments, but we shall concern ourselves mainly with the gramophone pick-up and the loud speaker. The other devices, whilst of vital importance to the functioning of sound-reproducing apparatus, will only be referred to in passing. The gramophone pick-up is a device for converting mechanical energy into electrical energy; the loud speaker functions in the reverse manner, converting the electrical energy, supplied to it by the output valve of an amplifier, into sound-wave energy (which is mechanical in nature). The microphone is similar to the loud speaker, but the energy transfer takes place from sound waves to electrical impulses. Automatic recording apparatus, mechanical relays, parts of television equipment and electric gramophone motors are further examples.

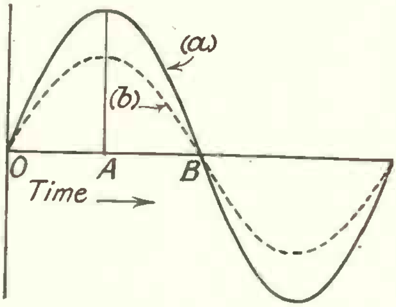


Fig. 1.—Two Superimposed Sine Waves.

"Intelligible" Energy

The energy handled by gramophone pick-ups and loud speakers is what might be termed "intelligible" energy, *i.e.*, energy which, by the use of a suitable medium (called by engineers a TRANSDUCER), can be converted into intelligible form, either speech or music. The intelligible form of the energy is that of sound waves, and the corresponding electrical form is that of alternating currents and voltages of the same form and frequency as the sound waves, and, in fact, corresponding *exactly* to the sound waves.

The word "exactly" is stressed, as it involves correspondence in three distinct ways, and, in order that we may investigate this correspondence further, we must first revise, and add to, our knowledge of waves and of alternating currents and voltages (see previous sections in this series).

Phase

We are already acquainted with the significance of the term sine wave, and with the terms frequency, period (periodic time), wavelength, velocity, amplitude, maximum amplitude and instantaneous amplitude, when applied to alternating current and voltage waves in an electrical circuit and to wireless waves. We now meet a new term, viz., PHASE.

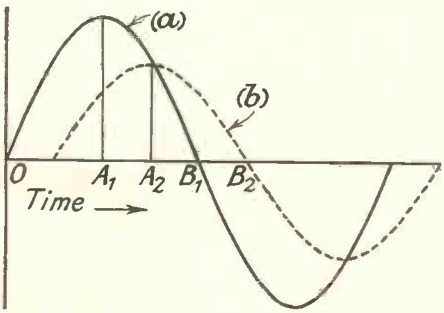


Fig. 2.—Diagram showing Two Waves out of Phase.

In Fig. 1 are shown two superimposed sine waves, one curve is shown in a full line (*a*) and the other in a dotted line (*b*). It will be seen that their frequencies are the same, but their maximum amplitudes are different, that of (*a*) being greater than that of (*b*). Also they start off together at O, reach their respective maxima at the same time at A, reach the zero amplitude together at B, and, in fact, are everywhere "in step." The term IN PHASE is used to express this fact. When the waves are "out of step," as in Fig. 2, they are said to be OUT OF PHASE, and when they are as much out of phase as possible—*i.e.*, when the maximum positive amplitude of one wave coincides with the maximum negative amplitude of the other—they are said to be IN OPPOSITE PHASE, as in Fig. 3.

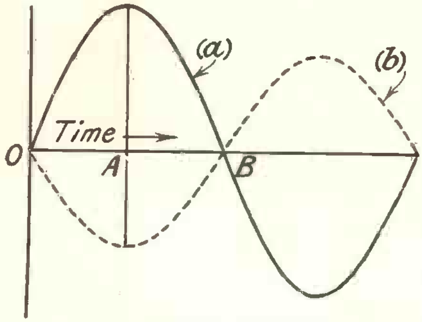


Fig. 3.—DIAGRAM SHOWING TWO WAVES IN OPPOSITE PHASE.

Phase Difference

It is possible to measure the difference in phase between two waves; the difference is called the PHASE DIFFERENCE, and is measured in degrees, as an angle. The following explanation makes this point clear:—

In Fig. 4 consider the line Op, which is the radius of the circle. Suppose that Op swings steadily round O, taking up successive positions Op_0, Op_1, Op_2, etc., and suppose that we draw a graph showing the distance of the point p above and below the horizontal. We shall measure times along the horizontal axis as shown. If the line makes one complete rotation per second, then the height at P_1 (position Op_1) is reached in one-eighth of a second, that at P_2 in a quarter of a second, and so on. It will be observed that the curve obtained is similar to a sine curve. In fact, the curve, $P_0 P_1 P_2 P_3 P_4$, etc., *is* a sine curve, and readers familiar with simple dynamo theory will remember that this is the basis of the theory of the production of alternating current and voltage from a simple alternator.

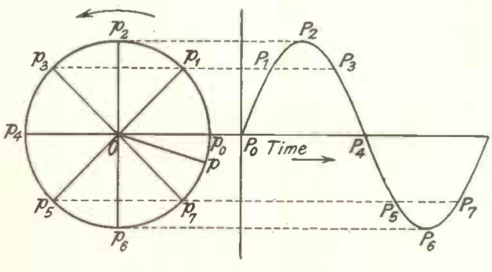


Fig. 4.—DIAGRAM ILLUSTRATING HOW A ROTATING VECTOR TRACES OUT A SINE CURVE.

Rotating Vector

One complete wave is produced by one rotation of Op. The number of complete waves produced per second is the frequency of the sine wave; hence the number of rotations of Op per second is equal to the frequency of the sine wave obtained above. We often refer to the radius Op as a ROTATING VECTOR.

We can express the amount of rotation of Op in terms of seconds (or fractions of a second), or in terms of the angle through which it has turned from, say, the horizontal position Op_0. Suppose, now, that we have two rotating vectors, as in Fig. 5, Op and Oq. When Op is horizontal q is below the horizontal. As they rotate (at the same rate) they each generate a sine curve, shown at P and Q, of different maximum amplitudes, since Op and Oq are of different lengths. It will be seen that P and Q are out of phase, P reaching its maximum amplitude before Q.

Now, if we vary the angle between Op and Oq—*i.e.*, the angle pOq, which is marked with a double line in the figure—we shall vary the phase difference between P and Q. The angle pOq is the measure of the phase difference, and, in the case of the example in Fig. 5, angle pOq = 45 degrees, and hence we say that P is 45 degrees out of phase with Q, and we can also say that P leads Q by 45 degrees, since P is ahead of Q as regards time. It will be clear that when P and Q are in opposite phase the phase difference is 180 degrees.

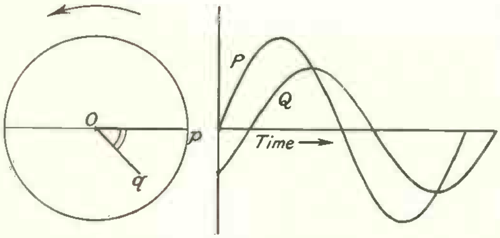


Fig. 5.—DIAGRAM TO ILLUSTRATE THE PHASE DIFFERENCE BETWEEN TWO WAVES.

Sound Waves

Sound waves are due to movements of air particles. *In vacuo* sound waves cannot exist, and readers will recall the well-known experiment of their schooldays in which a glass jar, containing an electric bell, is evacuated. As the air is withdrawn the intensity of the ring of the bell diminishes until, when a vacuum is established, no sound is heard.

How the Energy of the Wave is Passed On

From the to-and-fro movement of loud speaker diaphragms, it is evident that the air movements are due to alternate compressions and rarifactions. The air particles themselves do not move along with the sound waves; they move to and fro (*i.e.*, they oscillate) about a mean position, communicating the energy of the wave by collision with adjacent air particles which also commence oscillations about their mean positions. Thus the energy of the wave is passed on from particle to particle. This process is very similar to that which goes on in the elements of an electric circuit when an alternating current is passing, the movements in this case being those of the free electrons.

Displacement

If we draw a graph showing the displacement—*i.e.*, the distance away from the mean or average position—of any one of the air particles at any instant we shall obtain a sine curve. The frequency of the curve is equal to the frequency, or pitch, of the note, and its maximum amplitude determines the amplitude of the sound wave.

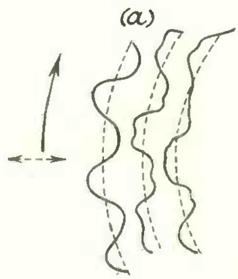


Fig. 6.—PLAN OF A PART OF A GRAMOPHONE RECORD.

On an enlarged and distorted scale.

Correspondence between Sound Waves and Electrical Signals

We are now in a position to discuss the correspondence between the sound waves and the electrical signals from the amplifier in the case of the loud speaker, and between the sound track on the record and the electrical signal fed to the amplifier in the case of the gramophone pick-up. There must be an exact correspondence in respect of:—

(1) Frequency.
(2) Amplitude.
(3) Phase.

Frequency correspondence seems almost an axiom, and it is at first difficult to realise how correspondence of frequency can break down. Consider, however, the case of the earlier horn type speakers, and of a good many present-day moving-iron speakers, which, when supplied with electrical impulses corresponding to the pedal notes of an organ, produce only harmonics of the note! Many people fail to observe this effect, because the ear, fortunately or unfortunately, supplies the missing fundamental note. Here is a case where exact frequency correspondence does not exist. A further example is that of the production of harmonics, by both gramophone pick-ups and by loud speakers, from a pure-tone source. The theoretical investigation of these faults in frequency correspondence is a difficult question, and no really adequate treatment has yet appeared, most of the work that has been done having been mainly of an experimental character.

Amplitude Correspondence

Amplitude correspondence implies that the relative amplitudes of the notes shall be maintained. Thus two notes, of relative amplitudes 1 and

2, should still have amplitudes in this ratio when reproduced by the loud speaker or when fed to an amplifier from a gramophone pick-up. When exact amplitude correspondence does not obtain, distortion occurs, both amplitude distortion and frequency distortion (see Section VIII. of this series) being forms of amplitude non-correspondence.

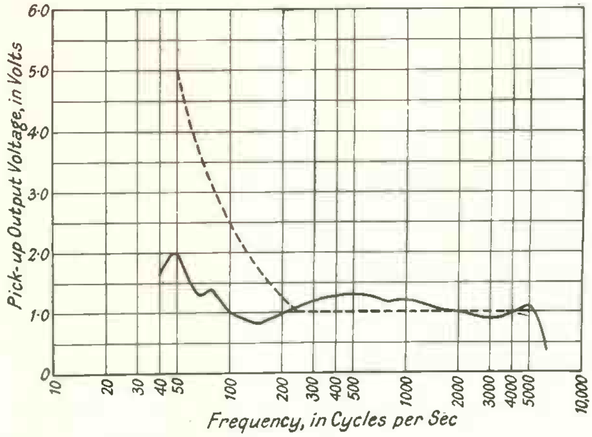


Fig. 7.—Typical Response Curve of a Gramophone Pick-up.

The phase difference between notes must also be maintained, and phase correspondence is said to obtain when the phase difference is maintained. Alteration of the phase relationship between notes results in a form of distortion known as phase distortion, to which, however, even the trained musical ear is, by good fortune, relatively insensitive under normal conditions.

High Degree of Perfection can be Obtained

No electro-mechanical system yet devised has been perfect, but a high degree of perfection can be attained. The total amount of allowable distortion depends almost entirely, in the cases we are considering now, on the discrimination of the human ear, and it would be useless to design a system in which the perfection was of too high an order to be appreciated except on paper. We are not concerned here, however, with the extent of the ear's discrimination, but with the more fundamental characteristics of gramophone pick-ups and loud speakers, and with the factors which limit the attainment of absolute perfection.

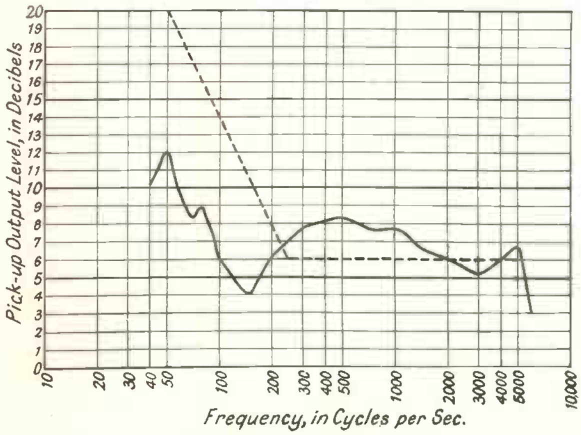


Fig. 8.—The Response Curve of Figure 7 Plotted on a Logarithmic Voltage Scale.

THE GRAMOPHONE PICK-UP

Fig. 6 shows, on an enlarged and distorted scale, a plan of a part of a gramophone record. The general direction of the groove is shown by the arrow in the full line, and the wavy lines are the sound track which the needle follows as the disc rotates. That is to say, as the disc rotates, the needle in the pick-up performs transverse movements, *i.e.*, movements at right angles to the general direction of the groove, as shown by the dotted arrow. The part of the sound track (*a*) in the figure comprises a pure sine curve representing a pure note.

Suppose that, for a note of frequency 500 cycles per second (c/s.), the maximum amplitude is 5 mils (*i.e.*, 5 thousandths of an inch). Then the following table shows the maximum amplitude at other frequencies in order that all notes shall be of the same intensity.

Frequency (c/s.).	Max. Amplitude (mils).
50	50
100	25
250	10
500	5
1,000	$2\frac{1}{2}$
5,000	1

Maximum Amplitude must be Inversely Proportional to Frequency

That is to say, the maximum amplitude must be INVERSELY PROPORTIONAL to the frequency, to use the language of the mathematician. The variation from 1 to 50 in column 2 is too wide a variation, and in actual practice the maximum amplitude of notes below a frequency of 250 c/s. is restricted, so that a form of distortion is introduced, bass notes being attenuated in comparison with notes in other parts of the register.

Similarly, notes of frequency above 5,000 c/s. are distorted by the recorder, and hence the gramophone pick-up should be designed to compensate for both of these deficiencies.

The reason for the limitation is that, in order to provide for large amplitudes, the grooves would have to be so far apart that the playing time of a record would be only a few seconds. In order to obtain a long playing time, and to prevent over-running of sound tracks, the restriction is introduced.

Bass Compensation

Reference to the output curve of any commercial gramophone pick-up will show that the designer has succeeded, in some measure, in obtaining bass compensation, although adequate compensation is extremely difficult to attain. In fact, the voltage generated at a frequency of 50 c/s. would have to be five times that at a frequency of 250 c/s., both sound tracks being due to notes of equal intensity.

How the Gramophone Pick-up is Constructed

The gramophone pick-up comprises an armature and one or more coils wound on a permanent magnet core. The motion of the armature, to which the needle is screwed, produces a voltage in the coils, due to the armature vibrating in the magnetic flux around the magnets. The extent and nature of the armature movement depends on its mass and its suspension in the pivot. The larger the armature and the greater its mass, the more difficult it is for it to vibrate exactly, as the needle is trying to vibrate in the sound track, especially at the higher audio-frequencies; it is easier to wave a walking stick over one's head quickly than to wave a heavy bar of iron.

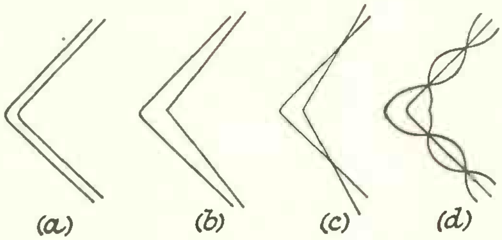


Fig. 9.—HERE ARE SEVERAL MODES OF VIBRATION OF A SIMPLE CONE.

(*a*) Simple forward movement; (*b*) greater movement at centre of cone; (*c*) part of cone moving forwards and part moving backwards; (*d*) complex movement at high audio-frequencies.

Note.—The extent of the translational and flexural movements of the cone are much exaggerated in order to give clear drawings. Edge of cone is free.

Inertia Effect

This opposition, as it were, of the armature, due to its mass and suspension, is called the INERTIA EFFECT of the armature. The smaller the armature inertia, the better the high-note response, since the needle can follow the sound track more easily.

Automatic Compensation for Recording Deficiency

A secondary effect arises here. We have just seen that it is necessary to compensate the bass response. This can be, and often is, achieved by producing a resonance in the pick-up mechanical system. That is to say, by so arranging the armature mass and its pivot so that, at a particular frequency, it vibrates naturally, just as an electric circuit has a natural frequency of oscillation, the pick-up automatically compensates for the recording deficiency. The frequency of the mechanical resonance must occur at the lower frequency end of the restricted range—50 to 250 c/s.—and the larger the armature inertia the lower the frequency at which mechanical resonance occurs. Hence armature inertia is a compromise between good treble-note response and useful bass-note resonance.

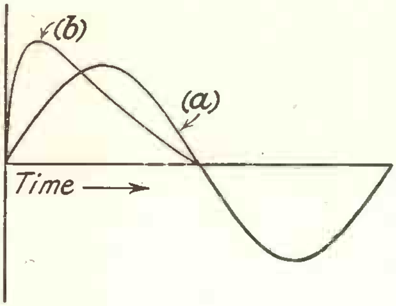


Fig. 10.—In this Diagram (*a*) is a Sine Curve representing a Pure Note, and (*b*) is a Curve with a very Steep Commencement.

Typical Response Curve

Fig. 7 shows a typical response curve of a gramophone pick-up, the voltages produced by notes of equal intensity being plotted against frequencies. It is evident that some bass compensation exists, but not perfect compensation. The ideal *shape* of response curve is shown by the dotted line. This voltage curve is not the only, nor by any means the best, form in which pick-up performance can be expressed. Designers often plot the logarithms of the voltages and so obtain the curve of Fig. 8. This is a more useful curve, since it expresses, in an easily interpretable form, how the *ear* responds to the fluctuations in the output, as shown by the voltage curve. This curve is often called an Output Level curve. The curve in Fig. 8 shows the output level corresponding to the voltage-frequency curve of Fig. 7. The units on the one axis are frequencies, as before, and on the other are Decibels. The ear can just appreciate a variation in level of 1 decibel (written db.). The dotted curve shows the ideal response in which adequate bass compensation is provided.

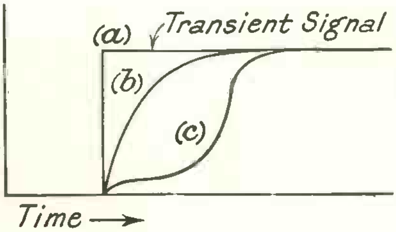


Fig. 11.—Here (*a*) represents a Transient Signal; (*b*) and (*c*) show Two Possible Modes of Response of a Speaker Diaphragm.

The points which we have considered only touch on the fringe of the host of problems which arise in gramophone recording and pick-up work, and readers who are further interested should read the papers which have been published on the subject, some of which are in the journal of the I.E.E. A paper entitled "Physics in Sound Recording," published by the Institute of Physics, also contains much relevant material.

THE LOUD SPEAKER

Many of the problems of loud speaker design are similar to those of gramophone pick-up design, but with slightly different initial conditions. As in the case of the pick-up, the diaphragm movement of a loud speaker must be inversely proportional to the frequency of the note in order that signals of equal intensity shall become sound waves of equal intensity. A compromise generally has to be effected, for the required movement at bass frequencies is too great. In a number of cases the compromise takes the form of employing a semi-rigid material for the diaphragm. If this is done, the diaphragm moves as a whole on bass notes, but only the centre part moves on treble and upper register frequencies. The treble output is thus reduced in comparison with the bass, so aiding compensation.

Modes of Vibration

Unfortunately, the diaphragm does not move quite so simply as this. Indeed, its motion is exceedingly complex, and we can only indicate here some of the simpler modes of vibration. Fig. 9 shows several modes of vibration of a simple cone. It will be observed that in (*c*) and (*d*) when one portion of the cone is moving forward, causing an air compression, another portion is moving back, causing a rarifaction. The compression tends to balance out the rarifaction, and the nett air displacement is often extremely small. This effect is more complex at the higher audio-frequencies. Those interested in experimental work on loud speaker diaphragms should read the many papers on the subject by Dr. N. W. Maclachan, published in *The Philosophical Magazine*, *The Wireless Engineer*, *The Wireless World* and elsewhere.

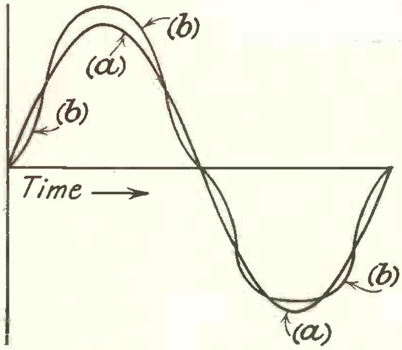


Fig. 12.—(*a*) Is a Sine Curve representing a Pure Tone Signal, and (*b*) represents the Armature (or Reed) Displacement due to the Current represented by (*a*).

Question of Inertia Effects

The question of the inertia effects of the moving parts—cone and armature or cone and speech coil—is highly important. As in the case of the pick-up, the greater the mass of the moving parts the more difficult it is to produce motion. Further, the higher the frequency of the note, the more difficult it is to produce movement. It is comparatively easy to wave our iron bar over the head slowly, but very difficult to wave it quickly.

Response to a Signal which is Impulsive in Form

A further problem exists in this connection. Suppose that we wish the diaphragm to respond to a signal which is impulsive in form? That is to say, a clear-cut, decisive note that starts off powerfully—a note possessing what the musician calls " attack." In Fig. 10 are shown two curves : (*a*) is a sine curve representing a pure note, and (*b*) is a curve with a very steep commencement. The sine curve represents the steady note, and the second curve represents a note with plenty of " attack." In the former case the current rises slowly, and in the latter it makes an almost sudden jump. The sudden jump of current in the loud speaker circuit does not invoke a sudden response from the diaphragm. The inertia of the moving system tends to prevent sudden movements, and thus the sound wave lacks the " attack " possessed by the signal.

It is the object of designers to introduce as much " attack " as possible into a loud speaker's response. Fig. 11 shows three curves : (*a*) represents a transient signal, *i.e.*, a signal with plenty of " attack," and (*b*) and (*c*) show two possible modes of response of a speaker diaphragm ; (*b*) is the quicker response, but (*c*) is preferable to (*b*), in spite of its extra time lag, because (*c*) builds up more rapidly and hence resembles the original signal (*a*) more than (*b*) does.

Harmonic Distortion

A problem which arises in the case of reed-type speakers is that of harmonic distortion. In the reed type of speaker the armature (or reed) moves towards and away from the magnets. When it moves towards the magnets the pull of the magnets increases, and *vice versâ*. This variation in attractive force causes wave distortion. Fig. 12 shows two curves : (*a*) is a sine curve representing a pure tone signal, and (*b*) represents the armature (or reed) displacement due to the current, represented by (*a*), flowing through the speaker windings. It will be seen that (*b*) is distorted from a sine curve. For the positive half cycle (*b*)'s maximum amplitude exceeds (*a*)'s, whereas, on the negative half cycle, it is less than (*a*)'s. That is to say, wave distortion has occurred, and it can be shown that the distortion represents the introduction of harmonics into the response. This lack of symmetry is overcome by the balanced armature system, in which the increased pull is compensated by a decreased pull of a second magnet, and *vice versâ*.

AUTOMATIC GRID BIAS FOR BATTERY RECEIVERS

By FRANK PRESTON, F.R.A.

It has become customary to obtain grid bias voltages for battery sets from small dry batteries, but this system has many disadvantages. In the first place it is impossible to vary the bias voltage in smaller steps than $1\frac{1}{2}$ volts and therefore a compromise has often to be made, and in consequence a certain amount of efficiency is lost. This is particularly noticeable in the case of valves which require a negative bias of only $1\frac{1}{2}$ to $4\frac{1}{2}$ volts and where a difference of $1\frac{1}{2}$ volts might amount to almost 100 per cent. of the nominal figure.

There is another difficulty which becomes apparent as the high-tension battery runs down, because for the valves to maintain a maximum working efficiency the grid bias voltage should be reduced in proportion to the fall in high-tension voltage; this is, of course, impossible in practice and so we must either contend with a certain amount of inevitable distortion or otherwise replace the H.T. battery some time before it is completely exhausted.

Both of the disadvantages referred to can be entirely overcome by employing what is popularly known as "automatic" grid bias. By this system the grid bias voltage can be fixed at exactly the correct value when the high-tension battery is new, and it will then regulate itself as the battery runs down, always being at precisely the correct figure.

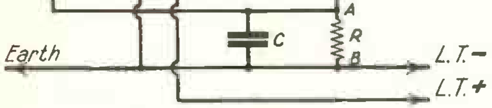


Fig. 1.—Illustrating the Principle of Automatic Grid Bias.

When H.T. current flows through resistance R, a voltage drop occurs, with a result that ends A and B are at different potentials, and A is negative in respect to B.

The Principle of Automatic Grid Bias

The principle of automatic grid bias is perfectly easy to understand and can best be explained by making reference to the theoretical diagram of Fig. 1 which shows the circuit of a power valve. High-tension negative is not joined directly to low-tension negative in the usual manner, but is connected through a fixed resistance (R). Thus, all the H.T. current which flows through the valve must first pass through this resistance.

We know that when current passes through a resistance a voltage drop occurs across it, the actual voltage being dependent upon the ohmic value of the resistance and upon the current. (The exact voltage can, of course, be calculated by the use of Ohm's Law, which states that the voltage is equal to the product of the current in amperes and the resistance in ohms.)

It can thus be seen that ends A and B of resistance R will be at a different potential, A being more negative in respect to B. If, therefore, we connect the grid of the valve (through the usual transformer secondary, grid leak, etc). to A, and one side of the filament to B, the grid will be biased negatively in respect to the filament.

By simple calculation we can find a value for R so that the correct G.B. voltage will be applied to the valve, and once this has been done the resistance will automatically regulate the grid bias voltage in relation to the voltage of the high-tension supply. In other words, as the voltage of the H.T. battery falls the anode current taken by the valve (and passed through the resistance) will with time become less. The voltage drop across the resistance, which is, of course, the grid bias voltage, will be diminished in the same proportion as the high-tension voltage and thus the valve will always be correctly biased whatever may be the state of the H.T. battery.

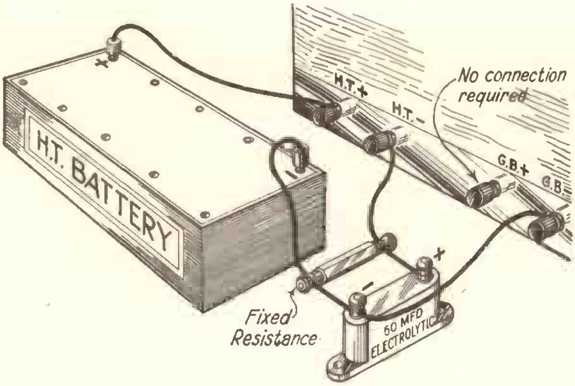


Fig. 2.—Showing how Automatic Grid Bias can be obtained in the Simplest Manner.

Preventing Instability

So as to prevent instability of the voltage drop in the resistance a fixed condenser marked C is connected across the resistance. This latter should be of high capacity. In practice it is found that a 1 or 2 mfd. condenser will work fairly satisfactorily, but much better results are to be obtained by using an electrolytic condenser of some 50 mfd.

Practical Aspects of Automatic Grid Bias

And now let us consider the practical aspects of automatic grid bias, beginning with a simple case, such as that of a three-valve S.G. receiver having only a single L.F. valve which has to be negatively biased. The method of connecting the necessary resistance and condenser is shown in the sketch of Fig. 2, and it only remains to find the correct value for the fixed resistance.

Finding the Correct Value for the Fixed Resistance

This can easily be calculated when the grid bias voltage required by the valve and the amount of current which will pass through the resistance are known. The bias voltage can generally be determined from the instruction sheet accompanying the valve, but it must be remembered that it is the figure applying at the voltage of the H.T. battery in use which is wanted, and not that which should be used when the valve is receiving the maximum permissible H.T. voltage. Next, the total H.T. current consumption of the set must be ascertained by connecting a milliammeter in series with the high-tension negative lead.

An Example

As an example, let us suppose that the correct grid bias is known to be -6 volts and the measured H.T. current consumption proves to be 10 milliamperes; the resistance value is then found from the formula: Resistance (in ohms) equals the required voltage drop divided by the current (in amperes), or more simply, $R = E/I$. On substituting our values we get $R = 6 \div 10/1{,}000$, which cancels out to just 600. The resistance should therefore be of 600 ohms.

Naturally, the answer will not always work out to an exact round figure like this, but if not, it will be quite correct to use a component of the nearest value available, since in any case the resistance is itself very largely self-regulating. That is, if its value is too high the resistance will pass slightly less current, whilst if it is too low it will pass rather more current, so that in either case the product of the ohmic resistance and current will remain more or less unchanged.

Connections for Electrolytic Condenser

It should be noted especially that the electrolytic condenser must be properly connected in circuit, for unlike ordinary mica fixed condensers, it is polarised. The terminals are marked "+" and "−" to indicate the proper polarity, and they should be connected in the manner shown in Fig. 2.

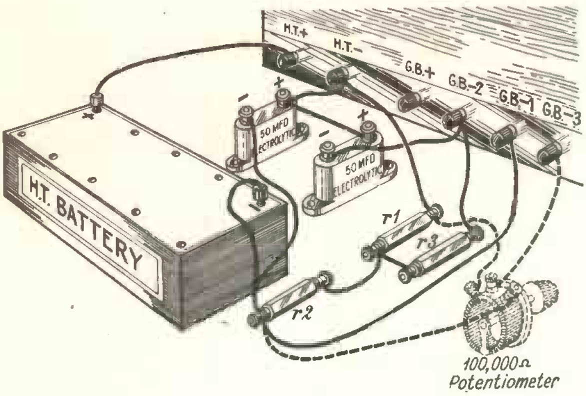


Fig. 3.—CONNECTIONS FOR AUTOMATIC GRID BIAS WHEN TWO OR MORE G.B. TAPPINGS ARE REQUIRED.

Obtaining Two or More G.B. Tappings

When two grid bias tappings are required by the set a different arrangement of biasing resistances becomes necessary and the connections will be like those shown in Fig. 3. It is assumed in this case that terminal "G.B. −1" takes the higher voltage, and this is derived from the "drop" across both resistances *r*1 and *r*2 which are connected in series. Terminal "G.B. −2," on the other hand, receives only the voltage dropped by *r*1. The resistance marked *r*3 is for de-coupling purposes only, and since it carries no current there will not be any voltage drop across it; the value of *r*3 may lie anywhere between 50,000 and 250,000 ohms. It will be seen that both grid bias tappings have a 50 mfd. electrolytic condenser across them.

Three or more different G.B. voltages could be provided in precisely the same way as described above by connecting further resistances in series. In every case the resistances must so be chosen that the voltage drop across them all is equal to the highest G.B. voltage required. De-coupling resistances should be used for every intermediate tapping to prevent instability being caused by back-coupling.

Resistance Calculations

The method of determining the correct value for *r*1 and *r*2 is practically the same as that previously explained. First we must find the sum of the resistances of *r*1 and *r*2 in exactly the same way as we found the value of the single resistance shown in Fig. 2. Next we can calculate the resistance of *r*1 after deciding on the voltage to be applied to terminal "G.B. −2," and then by simple subtraction the correct value for *r*2 is arrived at.

Another Example

Suppose we take another example and assume that the total H.T. current consumption is 12 milliamperes, that "G.B. −1" requires 9 volts and "G.B. −2" 3 volts. The total resistance of *r*1 plus *r*2 is given by substituting in the equation, $R = E/I$, and hence we get $R = 9 \div 12/1{,}000$, or 9,000/12, which works out at 750 ohms. In the same way the resistance of *r*1 is found to be 3,000/12, or 250 ohms, and so we see that *r*2 should have a resistance of 500 ohms.

Variable G.B. Voltage

If it were required to provide a variable G.B. voltage, such as would be called for when using a variable-mu valve, the simplest method would be to connect a high-resistance potentiometer in parallel with the fixed bias resistance(s), as shown in broken lines in Fig. 3. It can be seen that the outside terminals are connected across the points of maximum voltage-drop, whilst the variable grid bias potential is derived from the centre terminal. Since the potentiometer is in parallel with *r*1 and *r*2 its resistance must be very high in comparison with that of the fixed resistances, for otherwise it will reduce the grid bias voltage to something less than the calculated figure. In practice it will seldom be necessary to employ resistance values greatly in excess of 1,000 ohms, and so the potentiometer can be given a resistance of 100,000 ohms without there being any fear of affecting the normal functioning of the other bias resistances.

Unless suitable de-coupling is provided

in the set itself it will generally be necessary to insert a fixed resistance of some 50,000 ohms in series with the lead to terminal "G.B. − 3" and to connect a bypass resistance from the latter terminal to the H.T. negative one. In this instance the condenser will have to deal only with high-frequency currents, and so an ordinary fixed component of from ·1 to 1 mfd. will be adequate for the purpose.

A Disadvantage

The advantages of automatic grid bias have already been pointed out, so in all fairness the single disadvantage of the scheme should be mentioned. It is that since grid bias is in fact taken from the high-tension battery, the voltage of the latter will be reduced by the amount of the highest G.B. voltage obtained. In practice this will seldom exceed about 9 volts, but it is well to bear the fact in mind, and if possible to employ a battery having a voltage slightly in excess of that normally required by the set.

WHAT A CONDENSER ACTUALLY DOES

A CONDENSER stops *any* current from flowing, as no current can pass *through* a dielectric.

Engineers talk about a condenser "providing an easier path to earth." This statement, although generally correct and obvious to a trained man, is misleading to a beginner.

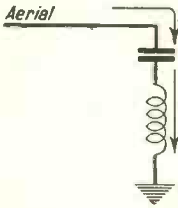


Fig. 1.—An accumulation of Electrons on the upper Plate of the Condenser will repel the Electrons on the lower Plate, and they will be pushed towards Earth.

It is all a question of electronic tides (Fig. 1). An accumulation of electrons on the upper plate of the condenser will repel the electrons on the lower plate, and they will be pushed towards earth, so that we have a simultaneous movement of electrons—from aerial to upper plate and from bottom plate towards earth. It appears therefore that a current flows *round* the circuit, although it does not pass through the condenser.

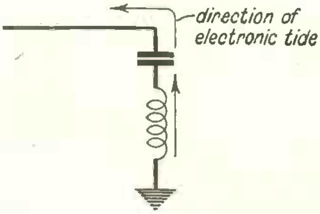


Fig. 2.—Here we see what happens when Electrons are retreating from the upper Plate of the Condenser.

Similarly (see Fig. 2), when electrons are retreating from the upper plate of the condenser towards the aerial they leave on the upper plate a number of unbalanced protons, and these protons attract towards themselves the electrons on the bottom plate as close to the insulation as possible. Hence, there is a movement of electrons from earth towards the bottom plate of the condenser.

Condenser across a Loud Speaker

In the case of a loud speaker (see Fig. 3), when a high-frequency current gets near the circuit it cannot go through the loud speaker windings on account of their high self-inductance, so that the high-frequency current finds it *easier* to swing the electrons to and from the plates of the condenser charging it in the process. When the charge on the condenser is sufficiently high and can overcome the self-inductance of the loud speaker windings, it will discharge through the loud speaker. As the condenser takes time to charge and discharge, the discharge current happens less frequently than the high-frequency current, and that is how we get the low-frequency (discharge) current.

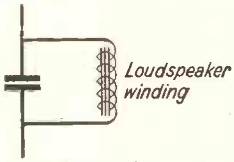


Fig. 3.—A Condenser across a Loud Speaker.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XXII—THE MAGNETIC CIRCUIT

WE have now to consider a class of electrical machinery which represents on one side the various sources of E.M.F., as distinct from primary and secondary cells, and on the other side a source of motive power. I have in mind the alternator and the dynamo, and the various kinds of electrical motors. Without study of these machines our work would not be complete, as one should have a clear idea of methods used in power stations for the purpose of supplying amongst other things our mains sets with the necessary power, and thus be enabled to deal intelligently with the design of that important part of the modern wireless receiver which is the intermediary between the mains and the receiving circuit proper.

Motor Generator Machines

Then there is a class of machines which appertain to wireless reception and are electrical machines which are used within the listeners' residences, viz., motor generator machines, which are a combination of a dynamo and a motor, the motor part being driven from accumulators and the so-called rotary convertors, which again consist of a motor run from D.C. mains and an alternator delivering A.C. power for an A.C. mains set.

But, in order to understand clearly the action of such machines, it is necessary to take a further step in our studies of magnetism and make sure of complete information about the so-called magnetic circuit.

A certain amount of information has already been given about magnetism and electro-magnetism in general, and now, once more, we shall pick up the loose threads and survey the whole subject in this article.

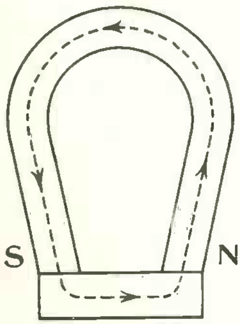


Fig. 1.—A TYPICAL MAGNETIC CIRCUIT.

Represented by a horse - shoe permanent magnet with a keeper across the poles. A single line of force of the magnetic field is shown so as to indicate clearly the path of the flux.

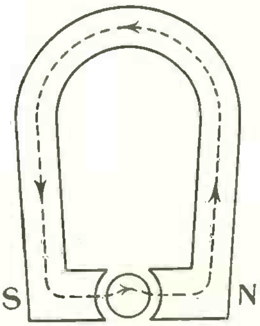


Fig. 2.—ANOTHER FORM OF MAGNETIC CIRCUIT.

Represented by a permanent steel horse-shoe magnet, a cylindrical piece of iron placed between the poles of the magnet and an air-gap between the magnet and the cylinder.

Similarity of Magnetic Circuit with Electrical Circuit

The reason why one talks about a magnetic circuit is that there is a certain similarity with the electrical circuit. In the electrical circuit we have a series of conductors across which is applied some form of an electro-motive force. If the circuit is a closed one an electrical current will flow against the resistance of the circuit, and the current will be limited by the magnitudes of the applied E.M.F. and the amount of resistance present. A circuit, similar to the electrical circuit, can be made up with the help of magnetic materials or magnetic "conductors," if you like, and when a *magneto - motive force* is applied to this circuit a magnetic flux will "flow" in the circuit against its *reluctance.*

Let us consider in detail these terms and see what they mean.

A Typical Magnetic Circuit

In Fig. 1 we have a typical magnetic circuit represented by a horse-shoe permanent magnet with a keeper across the poles. A single line of force of the magnetic field is shown so as to indicate clearly the path the flux follows within the magnetic material. The magnetic "circuit" is made up of two separate pieces of steel which form a closed path, just as electrical conductors form a closed circuit. The single line of force, one of many, is part of the magnetic flux within the material, flux that can be likened to the electrical current flowing within an electrical circuit. But it should be perfectly clear that in the case of the magnetic flux there is no actual movement of particles, but merely lines of strain set up in the ether as all molecules turn one way from the magnetic point of view.

Another Form of Magnetic Circuit

In Fig. 2 we have another form of a magnetic circuit represented by a permanent steel horse-shoe magnet, a circular cylindrical piece of iron placed between the poles of the magnet and an *air-gap* between the magnet and the cylinder. The path of a single line of the magnetic flux is shown once more, and it can be seen that as far as the flux is concerned the air constitutes a "conductor" of magnetic flux, and is therefore part of the magnetic circuit. That magnetic lines of force do pass through air we already know from our previous studies; we have seen the magnetic field around a bar magnet and between the poles of a horse-shoe magnet, we have also seen the magnetic flux around and inside a coil carrying an electrical current. You will notice that the line of force in passing from one medium to another is slightly distorted, a *fringing* occurs in the cylindrical piece.

This fringing, as well as *leakage* from the magnetic material into the surrounding air, is clearly shown in Fig. 3, which shows an iron core which is in part surrounded by a coil of wire through which a current is flowing, a current which causes the magnetic flux to come into being.

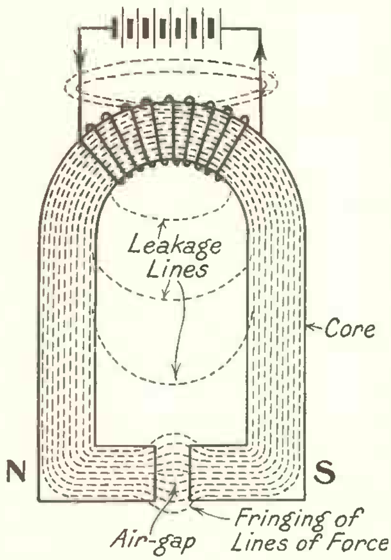


Fig. 3.—Diagram showing Leakage from the Magnetic Material into the Surrounding Air.

Here we see an iron core which is in part surrounded by a coil of wire through which a current is flowing.

In this case the magnetic circuit is formed by the iron core and the air gap. The bulk of the magnetic flux is concentrated within the iron and the air-gap. At the latter a certain amount of spreading out of the flux occurs (fringing), as if the air had less concentrating power than the iron and there is a certain amount of magnetic leakage taking place.

An Electro-magnet

Now let us consider this last magnetic circuit and see what is happening. The core, being of iron, is only magnetised when the coil of wire has a current flowing through it. This is what we call an *electro-magnet.* When a current is made to pass through the coil something happens to the molecules of the iron; they are made to turn one way so that the whole of the iron has a definite polarity. This means that some force has come into existence, a force which was absent when there was no current flowing through the coil.

Magnetisation by Induction

In Fig. 2 there is no contact between the horse-shoe magnet and the cylinder in between the poles, and yet the flux passes through it; in other words, the core is magnetised. This magnetisation is carried out by *induction*, and thus the flux is able to carry on. It is therefore clear that, given a closed or partly closed magnetic circuit, the force which causes the flux to jump into existence will act all round the circuit, using induction where necessary, so that the flux can go all round the "circuit."

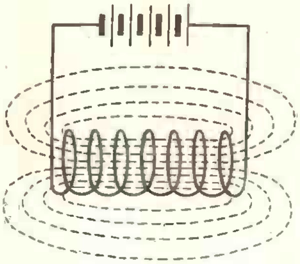


Fig. 4.—MAGNETIC FIELDS.

If a coil of wire is without a core, possessing magnetic properties, a magnetic field will come into existence when an electric current is flowing through the coil.

A Point to Bear in Mind

And here is a point to note. If a coil of wire is without a core, possessing magnetic properties, a magnetic field will come into existence when an electric current is flowing through the coil, as we can see from Fig. 4. If the same coil is mounted upon an iron core the flux will be much greater as, as soon as the iron core is magnetised, it will produce its own flux in addition to the flux brought into existence by the current in the coil.

Strength of Magnetic Effect

Having this in mind, let us take another step forward. In a coil, in the form of a solenoid (a name applied to a long single-layer coil), when it is carrying a current there will be a magnetic field around its turns. If we experiment with different strengths of current and the number of turns we shall find that the magnetic effect increases with the increase of either the current strength of the number of turns or both. Thus, we can say that *the magnetic effect is directly proportional to the current strength and the number of turns.*

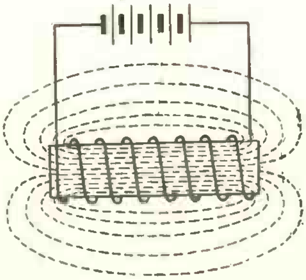


Fig. 5.—MAGNETIC FIELDS.

If the same coil shown in Fig. 4 is mounted upon an iron core the flux will be much greater as, as soon as the iron core is magnetised, it will produce its own flux in addition to the flux brought into existence by the current in the coil.

A Unit Magnetic Pole

Now let us take a unit magnetic pole. A unit magnetic pole is defined as follows: it is a magnetic pole which when placed a centimetre apart from another and equal pole will repel the latter with a force of one dyne.

Let us call the magnetic force acting upon a unit pole, placed within the coil carrying a current, H. In other words, H is the number of lines of force per unit area (square centimetre) in *air*.

It has been found by experiment that the strength of the field, that is, H, at the central point of the axis of a solenoid which has a much greater length than radius, is $H = \frac{4\pi}{10} \times \frac{T \times I}{L}$, where $\frac{4\pi}{10}$ is a constant number dependent upon the shape of the coil, T the number of turns, I the current strength and L the length of the coil in centimetres.

Ampere-turns

Now, it is customary in electrical engineering to lump the number of turns of a coil and the current flowing through it into a single product, and call this product *ampere-turns*, so that TI=ampere-turns, and denote this product by a symbol $\bar{A}$. Thus $\bar{A}$ stands for TI. Now if the length of the coil is L centimetres, then what the expression $\frac{TI}{L}$, which can be written as $\frac{\bar{A}}{L}$, means is *ampere-turns per centimetre.*

In this manner we can say that H is a constant multiplied by the ampere-turns per centimetre.

Since π is 3·1416, the constant $\frac{4\pi}{10}$ is (roughly) 1·25, and thus H is equal to 1·25 times the ampere-turns per centimetre.

An Example

To make this clear, if there are 100 turns in the coil and the current flowing through the coil is $\frac{1}{4}$ of an ampere, the ampere-turns, which is the product of the number of turns and the current, is $\frac{1}{4} \times 100$, or 25.

If the coil is 5 centimetres long, then the ampere-turns per centimetre are $\frac{25}{5}$, or 5.

Now let us remember :

H = magnetic force = the number of lines per square inch in air.

$$\mu = 1{\cdot}25\,\frac{\bar{A}}{L} \quad . \quad . \quad . \quad . \quad (1)$$

If we investigate the value of H along the axis of the coil we shall find that this force acting on a unit magnetic pole is about the same all along the axis till we come to the end of the coil, where it is about half of the previous value and diminishes still further as we go away from the end of the coil.

Magnetic Flux

As we have already seen, an iron core inserted within a coil of wire carrying a current will increase the number of lines of force. Let us call the total number of lines of force thus produced *magnetic flux* and denote this total number of lines of force by the letter F.

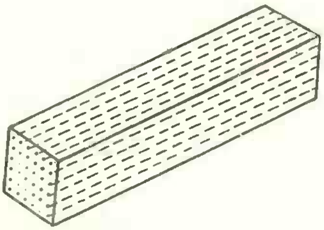


Fig. 6.—THE ABOVE DIAGRAM SHOWS WHAT IS MEANT BY FLUX DENSITY.

Flux Density per Unit Area

This being the case, we can introduce another term : *flux density per unit area*, say per square centimetre, and denote this by the letter B. Thus F = B × area of the magnetic circuit (taken at right angles to the direction of the lines of force). To make this clear, let us take the end of a magnet as in Fig. 6. Suppose that its end represents an area of 4 square centimetres. Also suppose that there is 1,000 lines of force per square centimetre (we arrive at this by counting the dots), then B or flux density per unit area is 1,000 lines and F total flux is 4,000 lines.

The more lines of force there are per unit area the greater must be the force acting upon a unit magnetic pole, so that H depends upon the number of lines per unit area in air.

Magnetic Permeability

In vacuum the values of H and B are equal. This also applies when the magnetic field exists in air. But when magnetic material is introduced they are not equal. There is a difference in the behaviour of different materials when lines of force of the magnetic field are passing through them. Some materials "conduct" lines of force better than others. Therefore, if we compare an identical coil with the same current flowing through it, we shall find that when there is no iron core B and H are equal, but when there is an iron core they are not. If we, therefore, compare the flux density per unit area in iron with that in air we shall arrive at the "conductivity" by the material of lines of force. This magnetic "conductivity" is called *magnetic permeability*, the term indicating that not all materials are permeated by the magnetic field in the same way. Permeability is denoted by the Greek letter μ (mu). Thus we can say that

$$\textit{permeability} = \frac{B}{H} = \mu.$$

Permeability of Magnetic Materials

Since B and H in air are equal, the permeability of air is unity. It is also unity in the case of all non-magnetic materials, and is as follows in the case of magnetic materials :

Material.	Maximum Permeability.
Wrought iron . . .	3,700
Cast iron . . .	380
Mild steel	8,350
Cast steel (annealed) . .	3,500
Cast steel (unannealed) .	1,700
Magnet steel (Tungsten) .	200
Magnet steel (hardened) .	200
"Stalloy"	4,800
"Lohys"	4,200
Cobalt	174
Nickel	296

A Summary

To sum up, we have learned up to the present that in discussing the magnetic circuit we talk of the total flux, which we denote by the letter F. This represents the total number of lines of force taken over the whole of the area of the magnetic path at right angles to the direction of the lines of force. When we talk about the flux per unit area *in air*, *i.e.*, the number of lines of force per square centimetre in air, again taken at right angles to the direction of the lines of force, we call this number of lines H, and when we talk about flux per unit area, *i.e.*, flux density, in materials other than air, we call this number of lines of force B.

The ratio of flux density in a magnetic material (B) to the flux density in air (H) is called the permeability of the material, and is denoted by the Greek letter μ, so that :

$$\mu = \frac{B}{H} \quad . \quad . \quad . \quad . \quad (2)$$

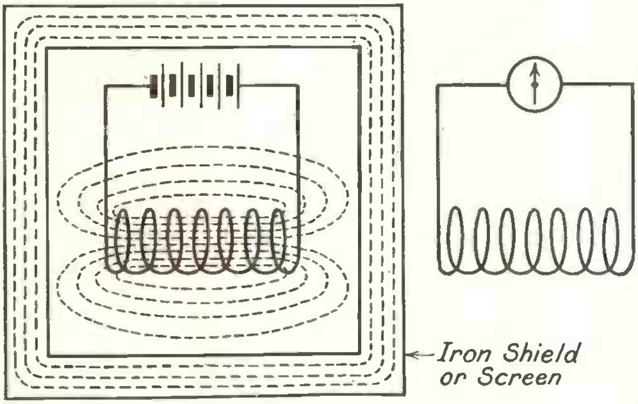


Fig. 7.—Screening a Magnetic Field.

If a source of magneto-motive force is not desired to affect the immediate space in its neighbourhood, we can surround this source completely by an iron screen which will concentrate the lines of force of the magnetic field within itself.

Magnetic Potential

If you recollect, the electrical difference of potential between two points has been defined as the amount of work done in ergs by carrying a unit electrical charge from one point to another. Similarly, the electro-motive force has been defined as the amount of work done in ergs by carrying a unit charge round the circuit. The electric potential of a point has been defined as the amount of work done by carrying a unit charge from infinity to the point.

If we now substitute a unit magnetic pole for the unit electric charge and move this unit pole in a magnetic field we can arrive at similar definitions. Thus a *magnetic potential* of a point is determined by the amount of work done in ergs by carrying a unit magnetic pole from infinity to the point.

Magneto-motive Force

A *difference of magnetic potential* between two points is measured by the amount of work done by carrying a unit magnetic pole from one point to another, and the work done by carrying a unit magnetic pole around a magnetic circuit should be the measure of a force similar to the electro-motive force in electrical circuits, *i.e.*, a sort of a magneto-motive force. This term *magneto-motive force* is used in electrical engineering, and is defined as the sum total of all the H's in a coil of wire carrying an electrical current, *i.e.*, the sum of all the magnetic forces.

$H = 1{\cdot}25\,\frac{\bar{A}}{L}$, *i.e.*, it equals the number of ampere-turns per centimetre. Therefore, the magneto-motive force (M.M.F.) must be equal to $1{\cdot}25\,\bar{A}$, *i.e.*, to the magnetic force exercised by the coil as a whole.

$$\text{M.M.F.} = 1{\cdot}25\,\bar{A} \quad . \quad . \quad . \quad (3)$$

Thus, as you see, we can easily ascertain the M.M.F.—the force giving rise to magnetic effect and therefore to the total flux in a magnetic circuit as 1·25 times the ampere-turns of the exciting coil. This magneto-motive force will grow with the increase of the number of turns, and it will also grow with the increase in the strength of current.

What this force does is to produce the total magnetic flux. But the total magnetic flux depends upon the permeability of the circuit. When comparing the electrical circuit with the magnetic circuit, we have said that the magnetic permeability is akin to the electrical conductivity. We know that in an electrical circuit the conductivity of the circuit is the reciprocal of resistance, so that conductivity $= \frac{1}{\text{resistance}}$.

Reluctance of a Circuit

For this reason there must be in the magnetic circuit something akin to resistance, something that should be in some way the opposite of permeability. This opposite of permeability we call the *reluctance* of the circuit, which is inversely proportional to the permeability. This reluctance is a sort of magnetic resistance to the passage of lines of force. Just like electrical resistance which grows with the length of the circuit and diminishes with the increase of the cross-sectional area of the conductor, so the magnetic reluctance grows with the increase in length of the magnetic circuit and diminishes with the increase of the cross-sectional area, and, just like resistance depends upon the resistivity of the material, so the magnetic reluctance depends upon the reciprocal of permeability.

In the case of an electrical conductor we have resistance $= p\frac{L}{A}$, where L is the length of the conductor, A the cross-sectional area and p is the resistivity per unit volume. Similarly, in the case of magnetic path, its reluctance $= \frac{L}{\mu A}$, where L is the length of the magnetic path, A its cross-sectional area and μ is the permeability of the material. Notice the slight difference between the two formulæ.

Now we have in the case of the magnetic circuit, the *M.M.F.*, the *flux* to which it gives rise, and the *reluctance* of the magnetic circuit which opposes the flow of flux.

An Analogy with Ohm's Law

In analogy with Ohm's law we should have the following relation :—

$$\text{Flux} = \frac{\text{M.M.F.}}{\text{Reluctance}}$$

and $$\text{Reluctance} = \frac{\text{M.M.F.}}{\text{Flux}}$$

But Ohm's law does not really hold good for all magnetic circuits, and for the following reasons. In the case of electrical conductors the resistivity (p) remains constant, provided that the temperature does not change. But in the case of magnetic circuits μ, the permeability, is not constant for the same circuit, but *varies with the flux density*, and therefore in the formula

$$\text{Flux} = \frac{\text{M.M.F.}}{\text{Reluctance}}$$

the flux is not proportional to the M.M.F., although it increases to some extent as the M.M.F. grows.

But this formula will hold good when the magnetic field is taking place in air, and there are no magnetic materials present. Therefore, *in air*

$$\text{Flux} = \frac{\text{M.M.F.}}{\text{Reluctance}} \quad . \quad . \quad (4)$$

As you see, one must go warily in calculating magnetic circuits.

Magnetic Screening

You no doubt realise that since magnetic flux will spread in air and in non-magnetic materials there is no such thing as a magnetic insulator. But this does not mean that we cannot isolate magnetic flux. It is possible to screen the magnetic field owing to the fact that the permeability of iron is higher than that of air. Thus, if a source of M.M.F. is not desired to affect the immediate space in its neighbourhood, we can surround this source completely by an iron screen which will concentrate the lines of force of the magnetic field within itself, as shown in Fig. 7.

The First Snag in Magnetic Calculation

The first snag in magnetic calculation is that if we know the M.M.F., we cannot calculate the flux as we do not know the permeability till we know the flux density, and we do not know the flux density till we discover the flux. For this reason the first thing we do is to calculate the ampere-turns necessary to produce the required flux, and this is done quickly with the help of tables which give the relation between the number of ampere-turns and the flux density in various materials.

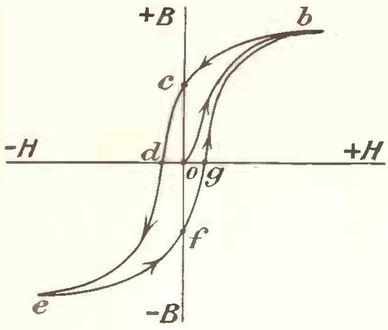


Fig. 8.—A Hysteresis Loop.

In the same table we can discover the permeability for the given flux density and then we can go ahead.

The calculations of magnetic circuits are brought down to such a fine art nowadays that the whole thing resembles more or less a piece of book-keeping. You look up tables and jot down the results. For this reason the design of electrical machines is also enormously simplified owing to the existence of a great amount of practical data, crystallised in the form of numerical tables and curves. What is more, with a lot of practice, one remembers such data, so much so that the author in his final examination in design of electrical machinery has been able, in common with a large number of other students, to design more or less completely four different machines in three hours.

Magnetic Hysteresis

It remains now to consider another important magnetic phenomenon known as the *magnetic hysteresis.* Magnetic materials do not demagnetise on the removal of the magnetising force in the same manner as they magnetise. Thus, when a piece of iron is placed within a coil of wire and the current in the coil, controlled by a variable resistance, is made to vary from zero to some maximum, the magnetisation grows with the current and reaches a maximum when the current reaches a maximum. Now, if the current be decreased from the maximum to zero again, it will be found that magnetism does not disappear completely, as soon as the current reaches zero, but that there is some *residual magnetism* left.

Retentivity

This property of magnetic materials to retain some of their magnetism, after the disappearance of the magnetising force, is called the *retentivity* of the material, and this retentivity is greater in some materials than others. It is possible, however, to demagnetise completely a magnetic material, which retained some of the magnetism communicated to it, by applying to it a reversed in direction magnetic force which will force or *coerce* the material to lose its magnetism. For this reason such a demagnetising force is called the *coercive magnetic force.*

Hysteresis Loop

In investigating the relation between H and B graphically during a complete cycle of magnetisation and demagnetisation, we shall arrive at a curve such as shown in Fig. 8. This curve is called the *hysteresis loop*. Following the line inside the loop, originating at O, we see that as H, *i.e.*, the magnetising force, increases, the flux density B also increases till a maximum is reached. Now, when we start reducing H, the curve, instead of following back the line *bo*, proceeds along the line *bcd*, thus showing that on demagnetisation the flux density B does not vary with the variation of the magnetising force in the same way as before. And when the magnetising force is reduced to zero, B remains of the value equal to *oc*, which is our residual magnetism.

Reversal of the Magnetising Force

Now if we reverse the direction of the magnetising force, we shall find that we have succeeded to bring down B to zero after we have used a reversed magnetising force equal in magnitude on our graph scale to *do* If we continue to increase the reversed magnetising force we shall find that B, after having reached zero, will also reverse in direction, and with the increase of the reversed H will grow to some maximum. If now we start to decrease H again we shall find that once more the curve will refuse to follow its old path, but will start along a new route, *efg*, till when H is made zero once more there is a flux density remaining equal in amount to *of*. On reversing H once more we bring down B to zero, and on increasing once more H we shall reach a maximum again.

What Happens in Practice

In practice, this magnetic hysteresis manifests itself in dissipation of useful energy in heat, and the area of the hysteresis loop represents, to some scale, the amount of energy thus lost.

This is highly important in wireless work, where the frequencies of currents are high, especially on the high-frequency side. This is one of the reasons why we do not use iron-cored components on the H.F. side. On the L.F. side, where iron-cored transformers and chokes are used, magnetic hysteresis may cause a considerable amount of distortion. This especially becomes obvious with cheap components, in which low grades, from the magnetic point of view, of iron are used. And this is the reason why you never see more than two L.F. transformer stages in a wireless receiver.

There is, however, a new development that comes from Germany in the form of the so-called Ferrocart Coils, which have an iron core made of tiny particles of high-grade iron. The iron particles are embedded in insulating material, so that eddy currents in them are reduced to a minimum as well as the losses due to such currents. This makes it possible to use coils having a ferrocart core in high-frequency circuits without the disadvantages that arise with solid iron cores. The exclusive rights in this country for the manufacture of such coils are conferred upon the well-known firm Messrs. Colvern Ltd., who specialise in coil design.

NOISES CAUSED BY LOOSE CONNECTIONS

MUCH trouble that is difficult to trace is due to faulty valve holders; whatever pattern or make is chosen, see that the valve pins make ample and certain contact and that such contact is likely to be maintained over long periods. Valves are comparatively heavy and vibrate constantly when the set is playing; consequently, unless a well-designed holder is used, the spring contacts open slightly and enormously increase the resistance, or are the cause of peculiar hisses and " mush."

Make sure, too, that wander plugs fit properly and that they have ample contact surfaces; indifferent fittings often cause high resistance and crackling noises.

Always make good, firm connections—see that every little detail is perfect; test anything with a moving contact—such as a resistance—to see that it works smoothly and that there are no " blind spots."

Pay heed to the numerous little detail fittings and refinements that come on the market from time to time, and always take trouble over the trifles; it is the little things that make or mar the success of any wireless receiver.

CONSTRUCTING A METAL CHASSIS

By WELLINGS W. WHIFFIN

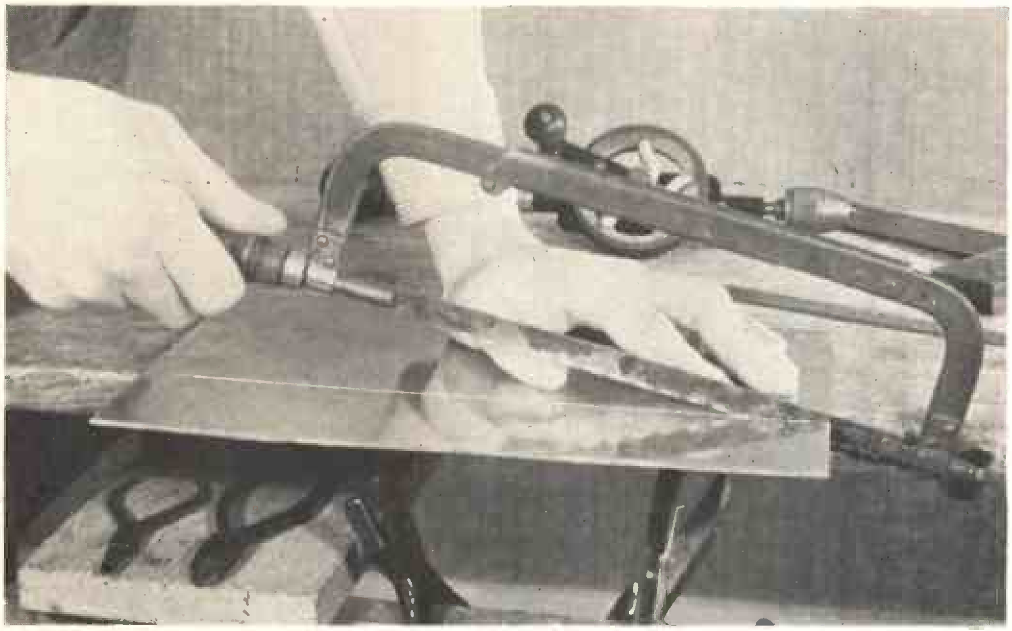


Fig. 1.—Showing how the Sheet is cut with a Hack-saw.

TO the great majority of radio manufacturers the assembly of components to a wooden baseboard with a vertical panel secured to it and holding a few more parts is non-existent. The amateur has been inclined to retain this method of construction, partly on account of its simplicity, but mainly because he thinks that the metal chassis requires tools and methods of manufacture beyond those at his command.

The metal chassis has decided advantages. In powerful receivers the metal base can be arranged to form a natural screening agent between parts of the circuit likely to interact, whilst in mains receivers the same principles apply in the prevention of mains hum. In very many instances the chassis can be of box construction in metal, in the interior of which the smaller components and the wiring can be safely hidden from accidental damage or dust. Even apart from these obvious advantages, there is a professional and satisfying finish to the metal-constructed chassis which in itself is sufficient to warrant its adoption. When the chassis is finished it can be painted or sprayed in aluminium or cream cellulose paint to give an extremely well-finished appearance and with the knowledge that, at any time, a rub with a damp cloth will restore its original freshness.

Choosing the Material

Sheet copper, tinned iron, aluminium or sheet iron or mild steel are the most suitable metals, and some consideration of their various properties is advisable before making a decision. Copper is not very often used on account of its comparatively high cost and the fact that it is very easily dented. When bending copper, secondary bends are likely to occur parallel to the required bend owing to the soft nature of the metal. It is very easy to solder, however, and shows a fine finish if polished and lacquered. Sheet iron is obtainable in various gauges, with a copper-plated covering on one or both sides. Thus, if a copper finish is required this material is to be preferred. It is more easily worked than copper sheet, a thinner gauge being chosen for the same rigidity.

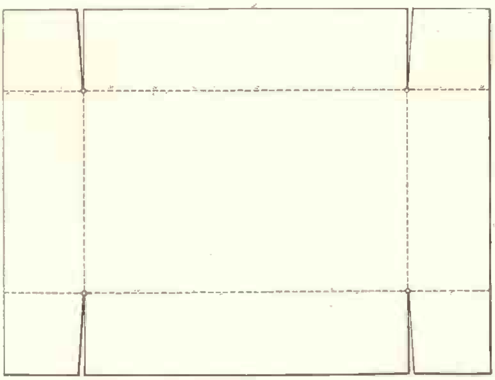


Fig. 2.—How the Tin is marked out before cutting.

Tinned Iron

Tinned iron or sheet tin, as it is usually called, is probably the easiest material for the amateur to work. It is obtainable in quite thin gauges capable of being cut with the ordinary tinsmith's snips or shears. It can be soldered rather more easily than copper, as the latter conducts the heat from the join too quickly and therefore requires a large and very hot soldering iron. Tin also forms an admirable magnetic shield, which under certain circumstances may be of advantage. In designing a tin chassis, plenty of space should be provided for tuning coils and other inductances, as the damping effect of the tin may be serious. In any case, it is advisable, where coils are to be tuned by ganged condensers, to arrange them in tin-shielded compartments of the same size and in the same relative positions. This will ensure that the damping effect of the metal is the same in each case.

Tin is less suitable if a large chassis is required. It cannot be sawn easily with a hack-saw, however fine the saw teeth, and in the thicker gauges it is difficult to cut with ordinary shears used in the home. In cutting tin, use a hack-saw with very fine teeth and hold the saw at a fine angle with the sheet (see Fig. 1). An old pair of leather gloves should be worn as a protection against cutting the skin.

Table showing Suitable Gauges of Metal for Chassis of Different Dimensions.

Size in inches.	Gauge or description in		
	Tin.	Aluminium.	Mild Steel.
10 × 6	XX	22	20
12 × 8	XX	20	20
14 × 9	—	20	18
16 × 10	—	18	16
18 × 12	—	16	14

Sheet Iron or Mild Steel

Either of these materials is suitable for the larger types of chassis or for the construction of metal boxes requiring magnetic and electrostatic shielding. They are used largely for the commercial construction of signal generators and other oscillators in which it is essential that the output shall be under complete control. Both metals will bend without heat with very small risk of fracture at the bend. The thickness selected usually permits of drilling and tapping holes, which obviates the use of nuts and bolts or rivets. Speaking generally, it is not advisable to consider soldering either of these materials.

Aluminium

If aluminium could be easily soldered it would be the ideal material for chassis construction. It can be bent successfully in quite a thick gauge, and even a large surface will retain its flatness. It can be worked, in suitable gauges, with either tin snips or with a hack-saw. Drilling and tapping aluminium sheet is rather more difficult than copper or iron, but it can be accomplished if reasonable care is taken. Aluminium has the advantage of possessing a finished surface when the sheet is purchased, and, unless this is spoilt in working, there should be no necessity to spray or paint the finished chassis.

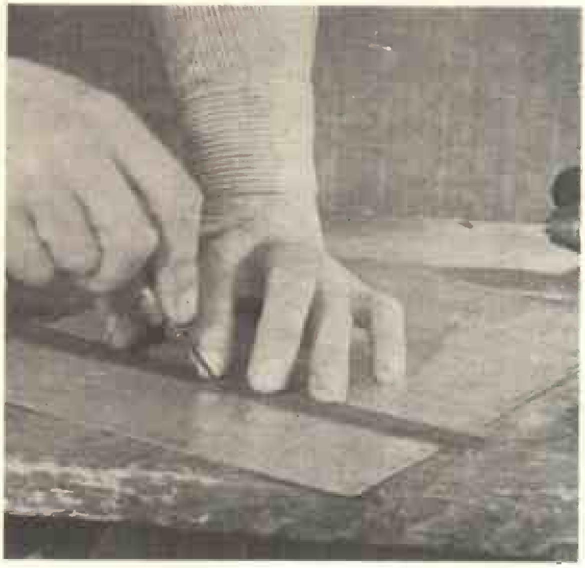


Fig. 3.—Using a Scriber to mark out the Sheet.

General Constructional Methods

In order to illustrate fully the various operations in the metals most likely to be used, the construction of three chassis will be explained, the materials used being sheet tin for the smallest size, aluminium, iron or mild steel in the medium size, and aluminium employing a special built-up construction suitable for the largest size, and for the manufacture of large screened boxes.

A Simple Chassis in Tin

Having chosen the size, the correct gauge sheeting is selected from the table given, bearing in mind that the dimensions given represent the largest unsupported surface of the chassis. If the components are exceptionally heavy or the heaviest placed in the centre of the largest face, then a heavier gauge tin will be more likely to resist buckling. The methods of marking out, showing the edges for cutting and bending, are given in Fig. 2, in which the dotted lines represent bends and the thick lines where the tin is cut. Fig. 3 shows the marking out of the sheet, using a sharp-pointed tool or scriber. Four $\frac{1}{8}$-inch holes are drilled at the corners indicated by heavy dots in Fig. 2. These holes assist in bending and prevent the formation of sharp corners.

Method of Bending

The method of bending is shown in Fig. 4. A wooden block having a sharp edge is pressed firmly against the edge to be bent. With the fingers covering as much of the side being bent to ensure uniformity of bend, the metal is pressed upwards to meet the other face of the bending block. If slightly rounded corners are required, the bending block must have its sharp edge removed with a file and then

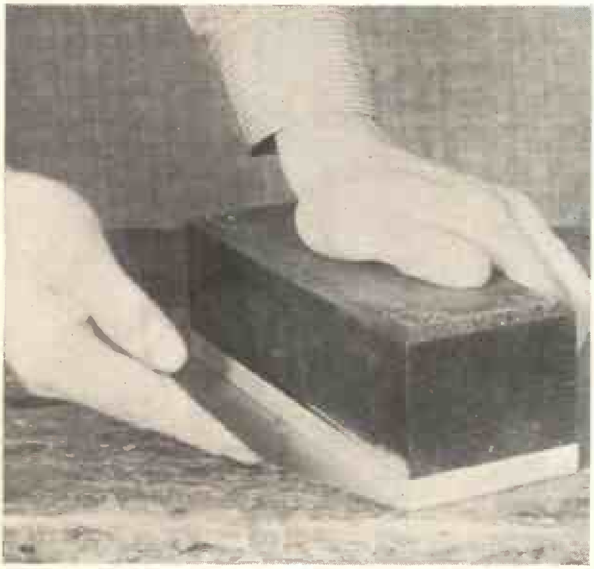


Fig. 4.—Bending up one of the Sides with a Block of Hard Wood.

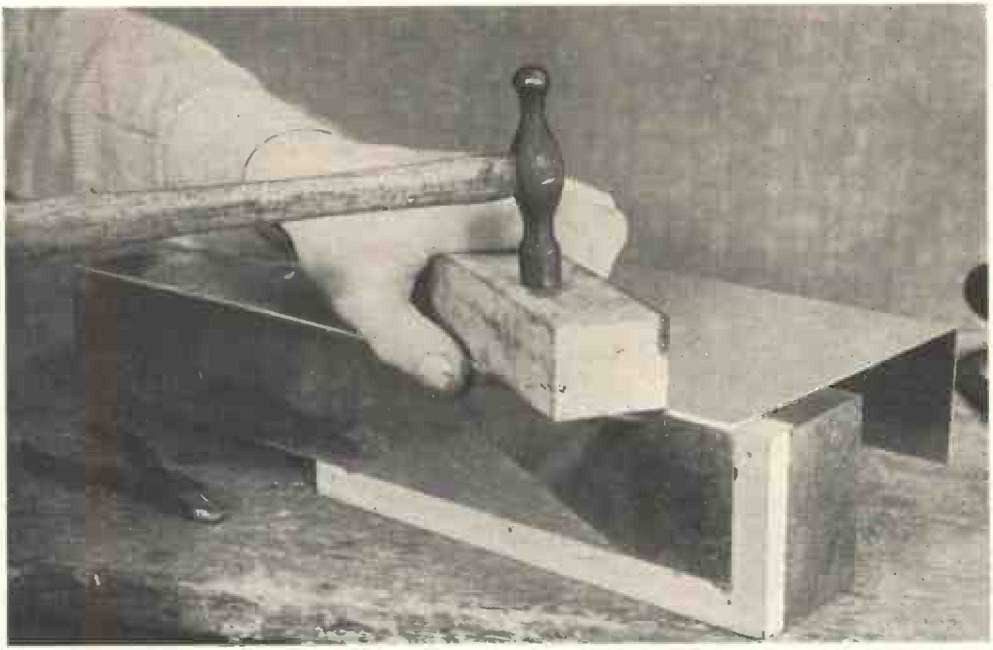


Fig. 5.—HAMMERING THE EDGES TO OBTAIN A SHARP BEND.

sandpapered. Sharp edges to the bends can be obtained by placing them in turn over the bending block, which is first secured to the work bench. A second piece of hard wood is placed over the edge and tapped sharply with a hammer, first with the top of chassis in position and then with the side (see Fig. 5). It is im-

Fig. 6.—SHOWING THE CHASSIS AFTER COMPLETING ALL BENDS.

portant not to hit the metal directly with the hammer, or a bruise will result, which is very difficult to remove.

Correcting a Bend

It will be seen that the short lugs are to be soldered to the longer sides of the chassis, the object being to strengthen them by the double thickness at the ends. The chassis, with bends completed, is illustrated in Fig. 6. If there are any edges which do not meet correctly, they may be put right by opening out the bend and then rebending in a more favourable position. In correcting a bend not properly placed, the block of wood must again be used for opening out the material.

Soldering the Lugs to the Sides

The sharp edges left after cutting are filed smooth and any unevenness in surface overcome by hammering between the hard-wood blocks. To solder the lugs, make certain that the sides are at right angles to the top of the chassis and hold in position with a pair of pliers (see Fig. 7). A hot soldering iron is then run along the seam on the inside (see Fig. 8). If the chassis requires further strengthening, some angle brackets can be soldered where necessary. If internal screening is used, the screens themselves can be fitted with projecting lugs for attachment to the top as well as the sides (see Fig. 9).

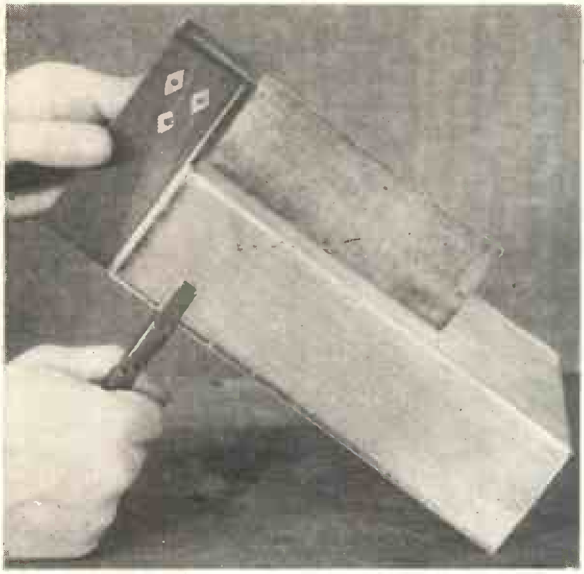


Fig. 7.—Squaring up the Chassis before soldering.

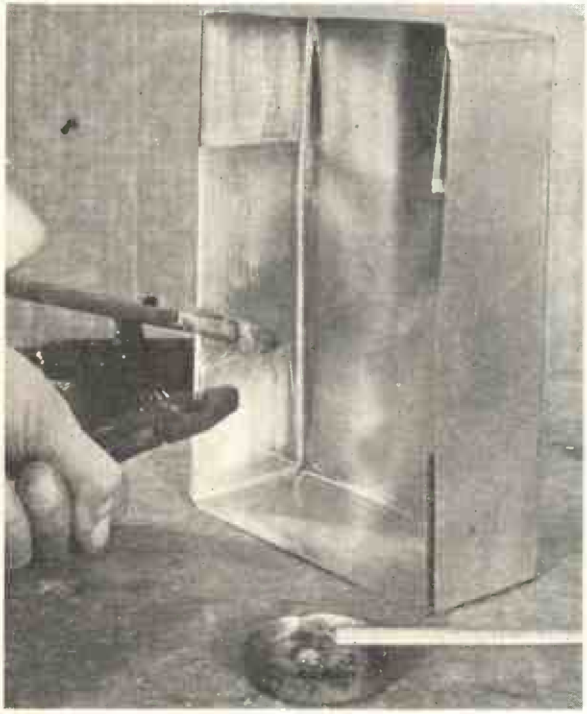


Fig. 8.—The Corners are held with Pliers when soldering the Lugs.

A Chassis in Aluminium

The chassis to be described is very easily constructed, the top and the two longer sides being bent from a single oblong piece of aluminium sheet. The shorter sides are cut afterwards, and to give adequate rigidity, they should be riveted or bolted to the main section.

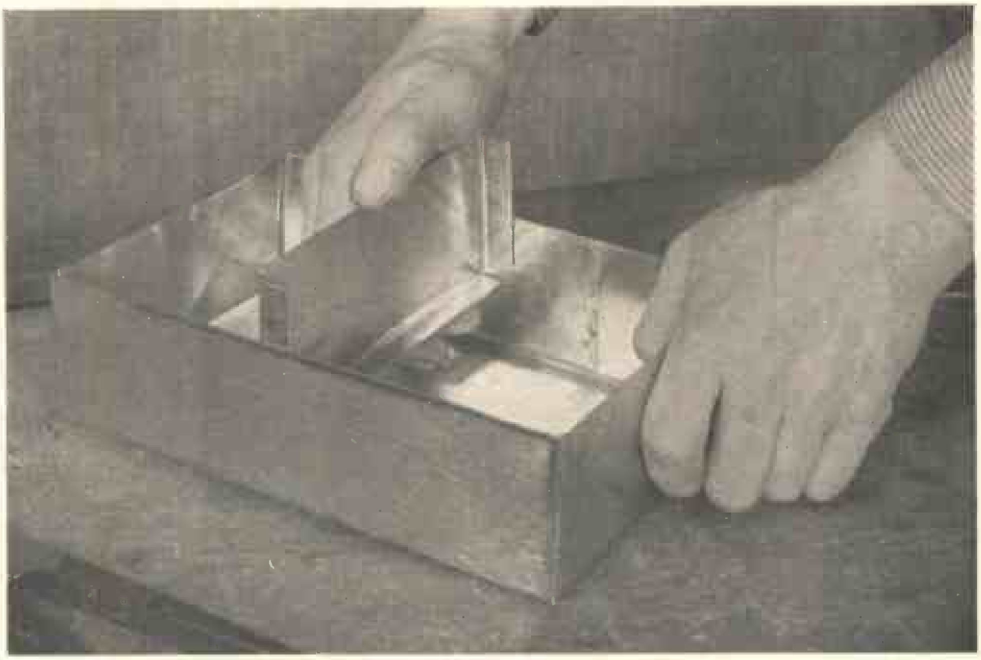


Fig. 9.—Showing how a Screened Partition may be fitted.

Having decided upon the sizes required for the top and the depth of the sides, the width of the former, from one bent-over edge to the other, is added to the sum of the depth of the two sides. The length of the chassis will be the same for top and sides, and therefore an oblong sheet can be cut up and squared to these two dimensions. Care must be taken that adjacent edges are exactly at right angles and that the ends are perfectly straight. The scribing marks which indicate the positions for the two bends must be parallel to ensure that the sides are of the same depth at all points. If this is not the case the finished chassis will rock about.

Method of Bending

The method of bending is the same as that described for the tin chassis. No real difficulty should be encountered, as aluminium sheet in a thickness up to 18 gauge bends quite readily. As there are no shorter side pieces to be considered at the moment, it is of advantage to screw the bending block to the work bench, with the end to be bent projecting over the edge, as shown in Fig. 10. Another piece of wood is pressed against the overlapping portion so that the whole is bent upwards at once. The bend is not likely to be so satisfactory if the operation is carried out bit by bit, that is to say, if one part is bent up in advance of another.

The work should now appear as shown in Fig. 11, after both sides have been turned into their final positions. The exact measurements for the two side cheeks can be taken from the half-completed chassis, which will rectify any error due to faulty bending. The completion of the work is made extremely simple by fitting two wooden ends to the chassis and screwing them inside the open ends so that the outer faces are flush with the metal edges. For those who desire to complete the chassis entirely in metal the method of riveting to be described may be useful.

How to Rivet the End-pieces

Having marked out the exact sizes of the end-pieces, an extra ½ inch of metal must be left at each side and at the top of each piece. In marking out the sizes, it must be remembered that these two pieces are to fit inside the main section and there-

Fig. 10.—Bending the Aluminium Sheet with a Block screwed to the Bench.

fore an allowance must be made for the radius of the two bends and twice the thickness of the material used. It is better to make one side bend correctly and then offer the piece up to the main section to scribe off the position for the second bend, which will leave only one radius and thickness to be considered. If the depth of the side-pieces is excessive, it is an easy matter to file them down at a later stage. A small quantity of aluminium round-head rivets, ¼ inch long and ⅛ inch in diameter, are purchased from an ironmonger. Holes are drilled round the edges of the top and sides of the main section at a distance of ¼ inch from the edge. The holes should be 2 inches apart and should allow the rivets to drop in without excessive side play.

The length of the rivet should be about $\frac{1}{16}$ to ⅛ inch longer than twice the gauge of the aluminium. Drill the holes in the main section only at first, and after offering the side-pieces to their proper positions mark with a scriber where the holes should come. Remove any burrs from the holes with a countersink or a larger size drill. Any raised metal will not permit close contact between the riveted surfaces. Place the sections to be riveted over a solid rod fixed in a vice with a rivet in position through one pair of holes. This operation is shown in Fig. 12.

The free end of the work is suitably supported to bring the height up to that of the riveting block. The head of the rivet is then hammered flat, preferably with a ball-peine hammer, as illustrated in Fig. 13, which shows the rivet head being turned. A series of fairly light taps with the rounded end of the hammer on the outer edges of the rivet will spread it over a large area, thus forming a head which will not allow the rivet to pull through under a strain.

Another Type of Aluminium Chassis

The method of construction to be described has the advantage of dispensing with any bending process, as each side and the top are cut to the measurements selected and the five pieces bolted together by means of ½-inch right-angle aluminium strip. As the strip is to be bolted over the outside edges, considerable work is saved. There is no need to finish the various panel edges smoothly, because they are hidden by the right-angle strip. This does not apply to the four bottom edges of the sides.

Allowances to be Made in Overall Sizes

If the overall dimensions of the finished chassis are important, as in the case of fitting it to an existing cabinet, careful reckoning must be made for the overlapping of the angle pieces and the projections of the screws which bolt them into

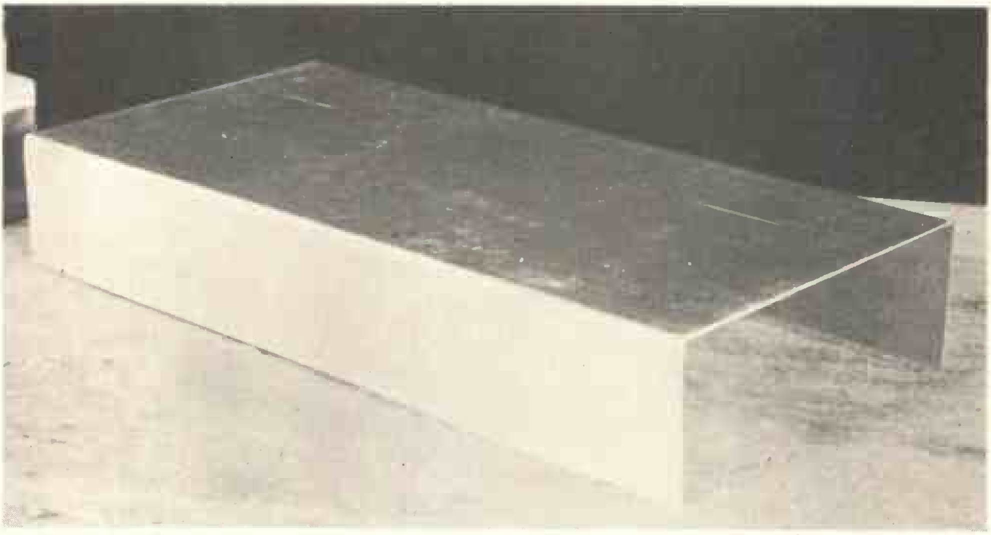


Fig. 11.—The Partly Completed Aluminium Chassis before the Sides are fitted.

position. If countersunk screws are used, this allowance need not be made.

Cutting the Panels

Cut the two longer sides of the same length as the top, so that the edges come flush when they are bolted to the angle strip. No. 6 or 4 B.A. screws, $\frac{1}{4}$ inch long, are suitable with cheese, round or countersunk heads, although the last mentioned will involve some extra work. The shorter of the side panels will have the same depth

Fig. 12.—How the Work is held during riveting.

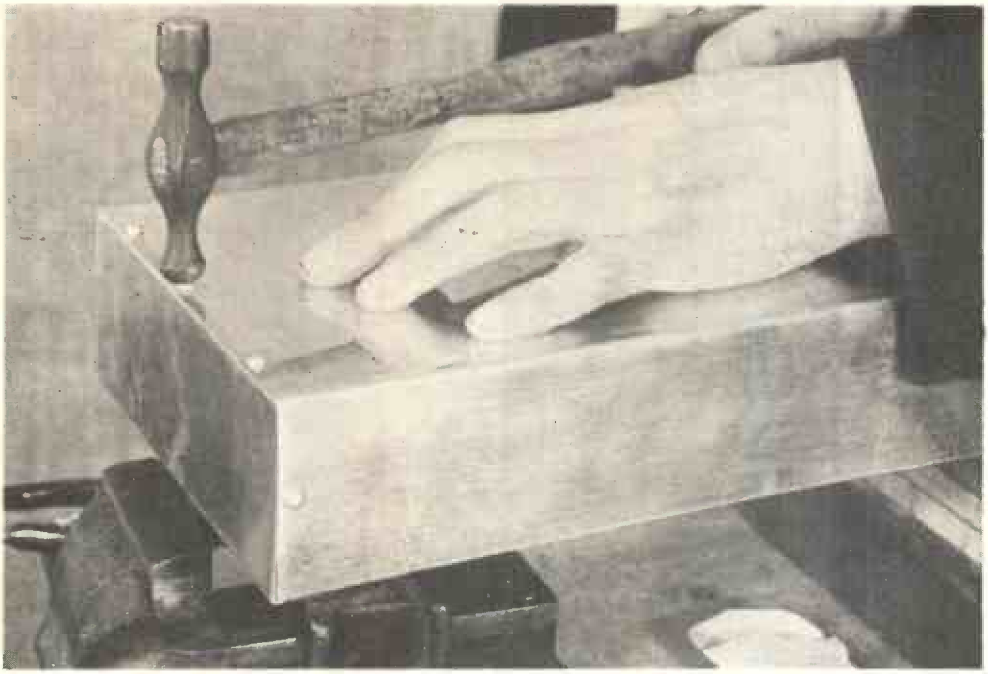


Fig. 13.—Using a Ball-peine Hammer on the Rivets.

A series of light taps with the rounded end of the hammer on the outer edges of the rivet will spread it over a large area, thus forming a head which will not allow the rivet to pull through under a strain.

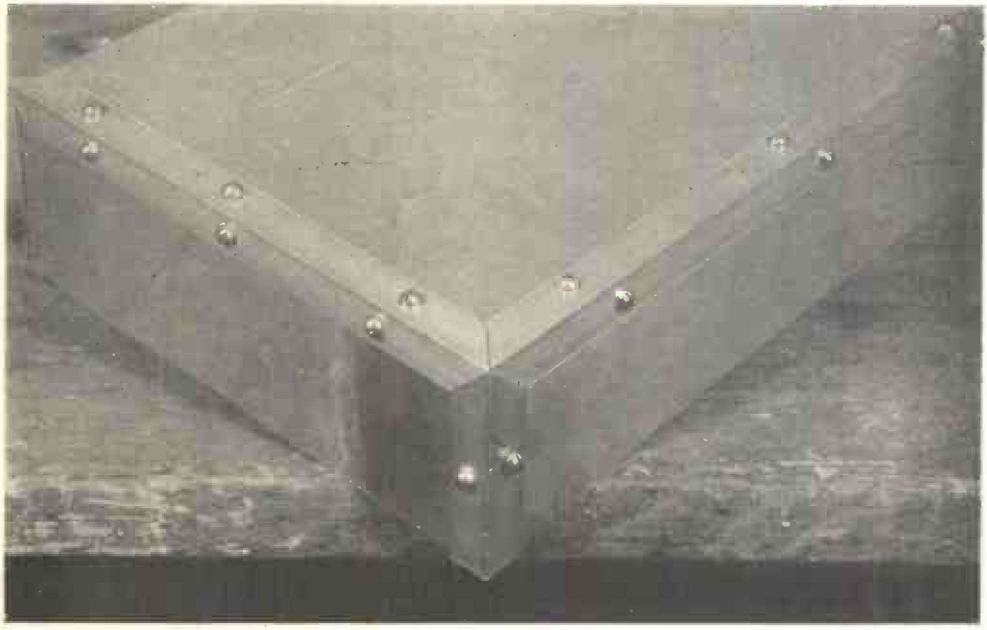


Fig. 14.—A Close-up view of the Mitred Corners.

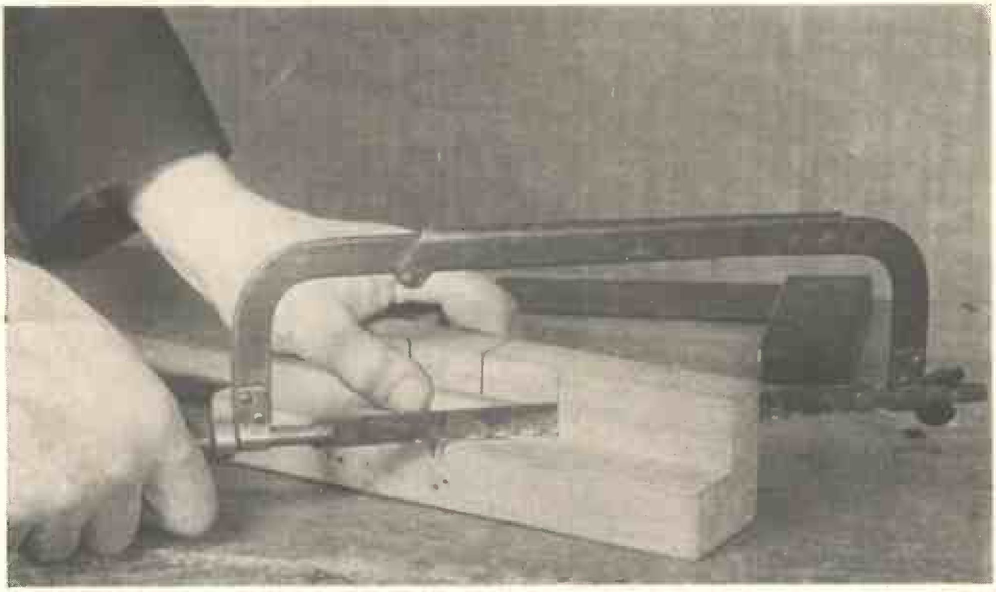


Fig. 15.—Showing how the Mitre Block is used.

Fig. 16.—Using an Expanding Bit for cutting Large Diameter Holes.

Fig. 17.—How an Oblong Hole is cut in Metal.

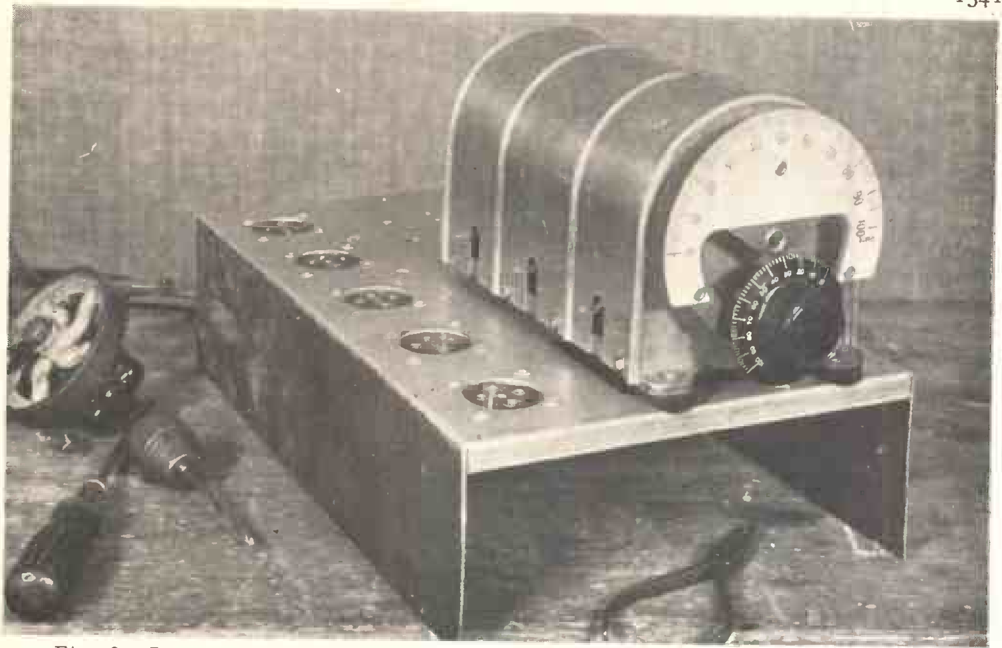


Fig. 18.—It is often necessary to mount the Gang Condenser on Rubber Washers.

as the longer two side-pieces, but their length must be less than the width of the top piece by an amount equal to twice the thickness of the aluminium. The screw holes should be spaced about 3 inches apart, taking care that the end holes are about 1 inch from the corners. Instead of sawing the ends of the angle strip flat, a

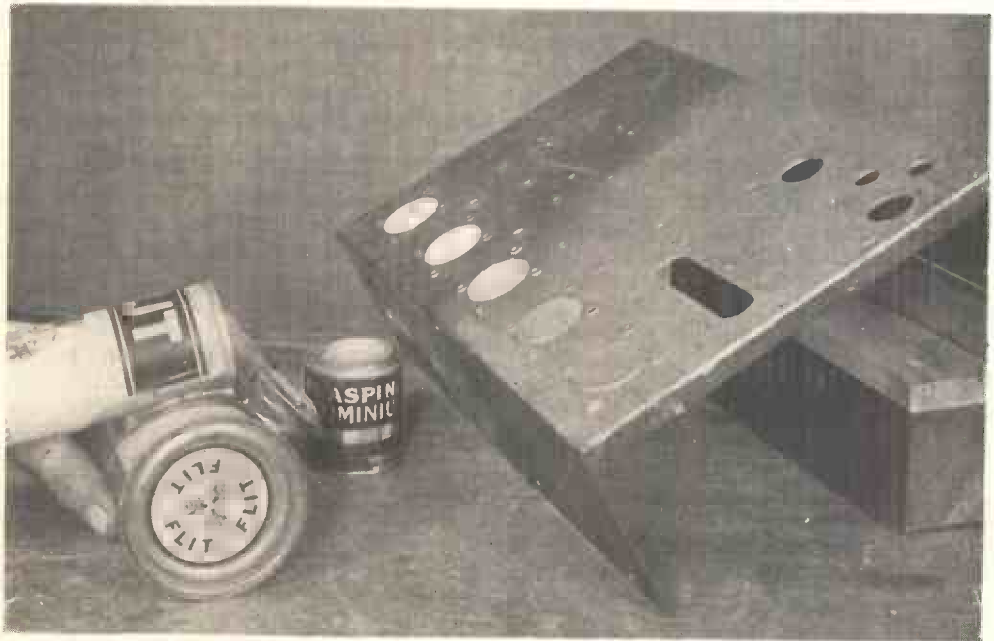


Fig. 19.—A simple but efficient method of spraying Cellulose Paint.

much better appearance is gained by mitreing them at an angle of 45 degrees, as shown in Fig. 14, which is a close-up view of a corner of the chassis so treated. An ordinary mitre-block can be used to obtain the correct angle, using a fine-toothed hacksaw, as illustrated in Fig. 15. A touch with a fine file after cutting will remove burrs and ensure that the resulting joins are close.

If any corner is found to gap open, it is easily put right by enlarging slightly the screw holes, so that the extra play in the movement of the angle strip can be used to cover up any small defect in cutting or in the measurements. It is important to note, if mitred ends are used, that all measurements in the angle strip must be made on the inside.

Fig. 20.—One Side of this Chassis has been removed to show the Construction.

the weak spot. In a powerful receiver, the chassis is frequently subjected to considerable vibration from the loud speaker. These vibrations, transferred to the vanes of the gang-condenser, may give rise to a sustained hum at one particular frequency, which dies down when the condenser is held firmly with the hand. To cure this fault mount the gang on rubber buffers in the same way as a gramophone motor is suspended to kill vibrations. A thick rubber washer is placed on either side of the chassis over the fixing bolts, the holes for which are enlarged to prevent direct contact between the bolt stems and the edges of the chassis holes (see Fig. 18). It must be remembered, in wiring, that the gang-condenser is now electrically insulated from the chassis.

General Constructional Notes

Large diameter holes for valve holders can be cut with an expanding bit, as shown in Fig. 16. Drill a hole of the size of the locating pin of the bit and cut the circle on each side of the metal until they meet in the middle. A half-round file can be used to finish off the edges if necessary. Another method of obtaining a large hole, of any shape, is to drill a chain of small holes and to open them out until the centre piece can be removed (see Fig. 17).

Loose Rivets or Bolts

Loose rivets or bolts may give rise to chattering or "tizzing" noises in the loud speaker. To locate the trouble or the presence of loose metal joints, tap the chassis in different places and listen for

Painting, Spraying and Lacquering

In painting or spraying, a cellulose paint is recommended, such as Brushing Belco or Luc. The work should be freed from grease by washing it in hot water, in which washing soda has been dissolved. Home spraying can be achieved successfully by the use of an insecticide sprayer, such as the "Flit" sprayer illustrated in Fig. 19. The nozzle of the sprayer should be about 6 inches from the work to be covered. Clean the sprayer out with thinners after use.

The operation of lacquering is very similar to that of painting if a cold lacquer is used. It is advisable to warm the chassis to drive off moisture before applying a coating. The writer has used a preparation called "Lacco," which has proved very successful. Most lacquers and cellulose paints contain celluloid, the insulating effects of which must not be forgotten when bolting components to the chassis. If any components have been fixed to the chassis before spraying they may be protected by covering them with paper before the operation and removing the paper when the spraying is completed.

Chassis in Mild Steel

Fig. 19 shows a partly completed chassis in mild steel in which the valve holders have been riveted in position first of all to avoid damaging the paint.

A More Elaborate Chassis

A more elaborate chassis involving considerable bends is shown in Fig. 20. It has been designed to hold all the radio components, including the loud speaker, which is bolted to the top of the vertical part through the bolt holes shown. One side of this chassis has been removed to show the section.

Where the Materials can be Obtained

If there is any difficulty in obtaining any of the materials mentioned from local dealers, it has been ascertained that Messrs. Stanton Brothers, of 73 Shoe Lane, London, are able to supply all the parts likely to be required.

COLOUR CODE FOR RESISTANCES

RESISTOR manufacturers now identify the value of their resistances by a standardised colour scheme. Figures are indicated by colours thus:

Figure.	Colour.
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Grey
9	White

How the Colours are Arranged

The colours are placed in three positions on the body of the resistance. The colour of the body indicates the first significant figure, the colour of the tip or end indicates the second figure; the colour of the dot indicates the number of noughts which follow.

How the Scheme Works

The following examples will make clear the working of the scheme :—

Body.	Tip.	Dot.	Value in ohms.
Yellow	Black	Red	4,000
Green	Black	Orange	50,000
Red	Green	Yellow	250,000
Red	Green	Orange	25,000

SERVICING

HIS MASTER'S VOICE 501 RECEIVER [FOR] D.C.

General Description

THE radio-amplifier unit comprises a screened-grid H.F. Marconi "DSB" valve, a metallised Marconi "DH" detector valve, and a Marconi "DPT" pentode output valve.

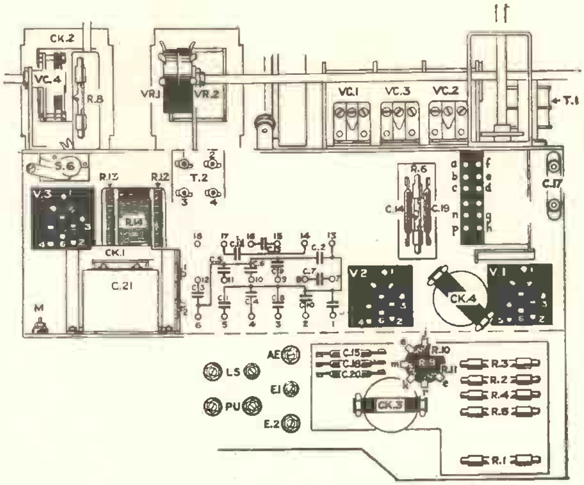


Fig. 1.—THE COMPONENT LAYOUT OF THE HIS MASTER'S VOICE 501 D.C. MODEL.

The pick-up is the standard H.M.V. Type 15 dealt with on p. 247, Vol. I, of COMPLETE WIRELESS.

The motor is the Type 25 His Master's Voice slow-speed, 40-volt motor, adjustable for mains voltage by a sliding calibrated resistor.

Consumption from the Mains

When radio only is being used, this varies from 50 watts at 195 volts to 65 watts when operating on mains of 250 volts.

When the motor is in use, the consumption, which will now include the heat loss in the motor-adjusting resistance and the motor wattage, lies between 90 and 110 watts.

How the Circuit is Arranged

Special attention should be paid to these notes before attempting any repairs or adjustments, as there are one or two special features of the circuit which may lead to confusion if not recognised.

The Valve-heating Arrangements

The circuit is arranged in two distinct portions as far as the mains supply is concerned: that portion supplying H.T. to the anodes of the valves, and the portion supplying current to the heaters of the indirectly heated valves.

The heaters of the valves are all arranged in series, being connected by brown wiring, the voltage to each heater being reduced to the 16 volts necessary at each valve holder by the tapped resistors R.12 (D.C. resistance, 80 ohms) and R.13 (D.C. resistance, 80 ohms), and the vitreous tubular resistor R.15 (590 ohms).

From the mains *plus* pin, therefore, the current passes to the valves *viâ* the switch S.6 (Fig. 3). Resistors R.12, R.13 and R.15 to the heater of the pentode valve V.3, passing thence *viâ* the detector and H.F. valve heaters through R.14 (near the resistances R.12 and R.13) *across* which the pilot lamp is connected (grey wire).

Special Note

In certain instruments a resistance lamp may be found in place of one of the voltage adjusting resistors with an additional resistor R.16.

How to Find a Burnt-out Valve

Careful tests are necessary to trace a burnt-out valve, since all valve heaters are in series. The best plan if one is suspected is to take out all the valves and check the continuity of each heater with headphones and battery or an avometer, or other similar device. Do not forget to test condenser C.21 (5 mfds. near V.3 holder (see Fig. 1)). It should be noted that if a valve heater is burnt out or the wiring discontinuous to the heater sockets, the pilot lamp will not glow, since it and the resistance across which it is wired are in series with the valve heaters.

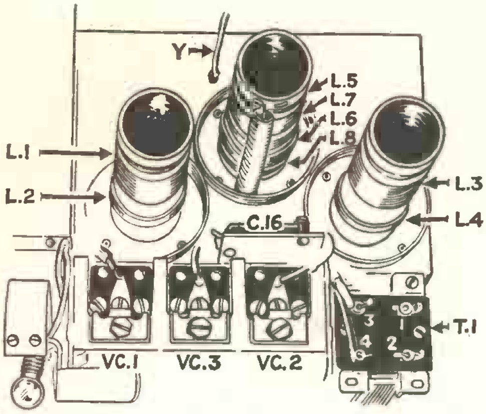


Fig. 2.—THE COIL FORMERS OF THE HIS MASTER'S VOICE 501 D.C. RECEIVER.

A burnt-out lamp, however, will not prevent the valves heating, since the current will still pass through the resistance R.14 (40 ohms approximately).

Test the Pilot Lamp

If burnt-out valves or defective heater wiring is suspected, test the pilot lamp at once. If this is found to be O.K., and resistance R.14 is O.K., there is definitely a fault either in the voltage dropping resistors or plugs or the valve heaters or valve-heater wiring. (Do not forget to check the valve pins for proper contact with the valve sockets.)

How the High-tension Supply is Arranged

It should be noted that there are two iron-core smoothing chokes in this circuit, one (CK.2) in the positive (+) lead and the other (CK.1) in the negative lead (−). The D.C. resistance of CK.1 and CK.2 should be 150 ohms each.

A further feature to be borne in mind when testing is that the chassis framework is *not* at H.T. — potential. This should be borne in mind when making voltage tests, especially at valve holders, since H.T.— is isolated from the chassis by fixed condensers, such as C.2, C.22 and C.4. The first two of these condensers being contained in the condenser case.

How H.T. is Fed to the Valves

H.T. positive passes *viâ* a red wire to lug 1 of the positive iron-core smoothing choke from lug 2 of CK.2 *viâ* red wire to the primary of the output transformer "T2," and the voltage dropping resistances R.2 (25,000 ohms), R.3 (100,000 ohms), R.4 (100,000 ohms) and R.5 (100,000 ohms) situated on the resistance rock near the H.F. valve holder (see Fig. 1).

Where to Look for a Failure of H.T.

A general failure points to an examination of the iron-core chokes CK.2 and CK.1 or smoothing condensers C.2, 3 or 4.

If no H.T. is found at a particular valve, the anode voltage-dropping resistance to that particular valve should be tested, and it should not be forgotten that, while an anode voltage supply may be found to the anode socket of the valve holder, unless the biassing resistors are intact, no current can flow through the valves.

How the Valves are Biassed

Biassing resistors are provided between H.T.−, as connected to CK.1, lug 1 and the cathodes of the various valves. The H.F. bias resistor being R.1 (2,000 ohms), the detector bias resistor being R.10, which is short-circuited out in the radio position, so that it only operates to give additional bias to the detector valve when it is being employed to operate as a gramophone amplifier. The pentode valve is biassed by the resistance R.11 (280 ohms).

Special Note about Resistances R.9, R.10 and R.11

Unless Fig. 1 is closely studied, these resistances, which are wound on a slotted bobbin, may be found difficult to identify.

The best way to check them is as follows :—

For R.9 measure between lugs *m* and *k*, as shown in Fig. 1 (D.C. resistance, 600 ohms).

For R.10 measure between lugs *e* and *j*

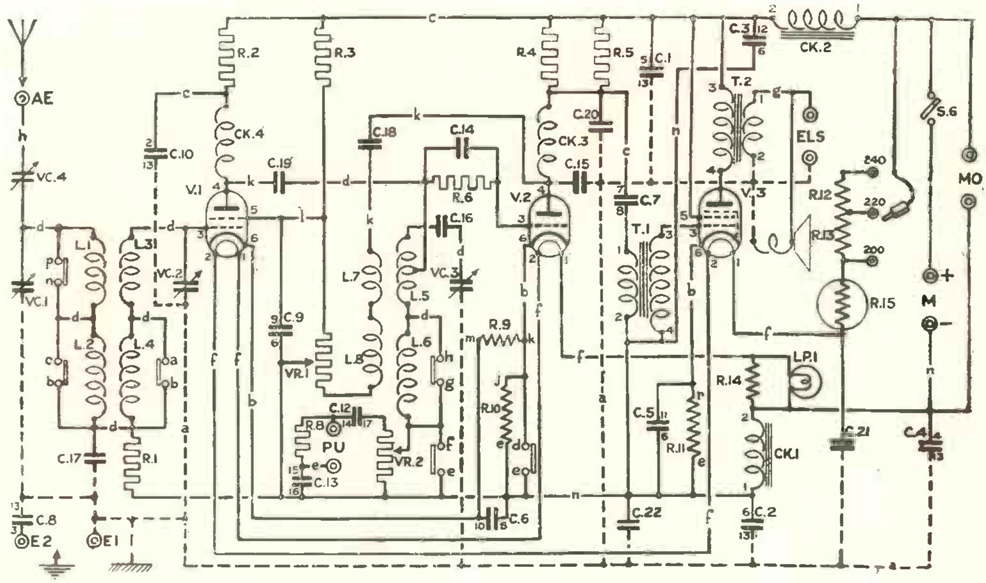


Fig. 3.—THE THEORETICAL CIRCUIT DIAGRAM OF THE HIS MASTER'S VOICE RADIOGRAM MODEL 501 FOR D.C.

on block bobbin (D.C. resistance, 1,000 ohms approximately).

For R.11 measure between lugs *r* and *e* (D.C. resistance should be about 280 ohms)

How the Pick-up is Connected

The screened cable from the pick-up head is connected to two blue plugs, which are connected to a braided cable leading to the radio chassis. (The plug earths the screening of the pick-up cable.)

It should be noted that the pick-up is isolated from any possibility of D.C. shock by the two condensers, C.13 and C.12 (lugs 15 and 16 and 14 and 17 respectively in the condenser " can ").

What to do if there is no Gramophone Reproduction

Make a test by listening with headphones at the two blue plugs when the pick-up is resting on a revolving record. If faint but clear music is heard here, the pick-up is O.K., if not, undo the small screw on the underside of the pick-up arm near the head and withdraw the pick-up head to see if the leads are intact on the soldering lugs mounted on the small paxolin strip. Further tests and adjustments on the His Master's Voice pick-up are described on pp. 247–252 of Vol. I of COMPLETE WIRELESS.

How the Tuning Circuits are Arranged

The general arrangement is as follows: the aerial feeds the signal to H.F. grid band-pass coils *viâ* a small variable condenser (VC.4) which is valuable, both as a selectivity and fine tuning control. It should be noted that if this condenser develops an earth, signals will be stopped.

The aerial to H.F. valve band-pass coils are switched so that the long-wave coil is shorted out in the medium-wave (MW) position. Also note the switch contacts " p " and " n," which short-circuit the medium-wave coil in the gram position to prevent radio " break through " in the gram position.

Signals from the H.F. valve are choke (CK.4) capacity fed to the grid coils of the detector valve (L.5 and L.6).

The audible signals from the anode circuit of the detector valve are resistance-capacity coupled (R.4, C.7) to the primary of the intervalve transformer (T.1), which feeds the grid of the pentode output valve.

How to Check up the Tuning Coils

A glance at Fig. 3 will show that the usual practice of checking resistance across

VOLTAGE AND CURRENT READINGS OF VALVES

All Readings taken with Volume Control Full On. All Readings taken on Avometer scale indicated. Readings taken with all Valves in Position.
SPECIAL NOTE.—Terminal 2 or 4 on Transformer T 1 must be used as an artificial earth, as the chassis and the earth socket are isolated from H.T. by condensers.

Valves.	Location.	Appearance.	Temperature.	Function.	Anode Feed. D.C. m.a.	Avo Scale.	Anode to Artificial Earth Volts. D.C.	Avo Scale.	Screen Feed. Milliamps. D.C.	Avo Scale.	Screen to Artificial Earth Volts. D.C.	Avo Scale.	G.B. Volts.	Avo Scale.	NOTES.
DSB	Left	Metallised	Warm	H.F. Amplifier	1·4	·012 amp.	150	1,200 volts	0·5	·012 amp.	25	120 volts	1·0	12 volts	Grid Bias measured between cathode and artificial earth.
DH	Centre	Metallised	Warm	Detector	Radio 2·6* Gram. 1·8	·012 amp.	Radio 40 Gram. 50	120 volts	—	—	—	—	Radio — Gram. 1·8	12 volts	Grid Bias measured between cathode and artificial earth.
DPT	Right	Glow	Hot	Output	30	·12 amp.	170	1,200 volts	8*	·012 amp.	210	1,200 volts	10·5	12 volts	Grid Bias measured between cathode and artificial earth.

NOTE.—The filaments of the valves are in series with the main voltage dropping resistor R.15 and the voltage-adjusting resistances R.12 and R.13.
The current through a meter inserted at one of the valve sockets (valve removed) should be approximately 0·25 amp.
The voltage drop across a valve is approximately 16 volts (Avo scale 120 volts).
All the above readings were taken on a 225-volt supply and therefore if YOUR supply is different, the readings (especially high-tension voltages) will vary proportionately. The filament voltage and current should, however, be within + 10 per cent.

* There will be a slight variation here, dependent on strength of signal.

the vanes of the gang condenser is not possible, as in the case of L.1 and L.2 condenser C.17 is in series, in the case of L.3 and L.4, R.1 is in series, and in case of L.5 and L.6, C.16 prevents a direct continuity test. The best test points for the coils are given below :—

For "L.1" and "L.2" and contacts "c" and "b," measure between *green* terminal of C.17 and *green* lug of VC.1. Correct result: 4 ohms for "MW" position of switch and 26 ohms for "LW" position of switch.

For "L.3" and "L.4" and contacts "a" and "b," measure between green terminal of C.17 and the grid socket of the H.F. valve holder (V.1). Correct result: 4 ohms for "MW" and 26 ohms for "LW" position.

For "L.5" and "L.6" and contacts "g" and "h," measure between the grey end of "R.1" and the green shielded lug of C.16. Correct results: for switch in "gram" position, open circuit; for switch in "MW" position, 4 ohms; for switch in "LW" position, 27 ohms.

The Reaction Coils "L.7" and "L.8"

Measure between two *outer* yellow lugs on coil former (see Fig. 2). Correct result should be 12·5 ohms.

Resistances of Transformer Windings

Intervalve transformer, primary, 1,000 ohms; intervalve transformer, secondary, 10,000 ohms; output transformer, primary, 1,000 ohms; output transformer, secondary, ·9 ohm. (Disconnect speaker coil when measuring secondary.)

COLOUR WIRING CODE

The instrument is wired according to a colour wiring system which will be found of the utmost value in tracing circuits.

Black, True Earth Circuit; White, Cathodes when not at Earth Potential; Red, High Tension D.C. Circuit; Yellow, Anode Circuit; Green, Grid Circuit; Brown, Filaments; Blue, Pick-up Circuit; Light Blue, Pick-up Circuit Low Potential Side; Pink, L.S. Output after condenser or transformer; Violet, Aerial Circuit; Orange, Mains; Yellow (Red Tracer), Green Grid Circuit; Yellow (Black Tracer), Pentode (Screen Grid Circuit); Grey, used for leads not falling within the usual Colour Code.

ELECTRIC GRAMOPHONE MOTORS

SECTION II.—H.M.V. TYPES 24 and 25; B.T.H. TYPE Y.L.

H.M.V. TYPE 24 A.C. INDUCTION DISC MOTOR

THIS motor is employed on Model 501 Radiogramophone, 532 Radiogramophone, and 523 Radiogramophone; also on playing table 116 and automatic playing table 117.

The Voltage Adjustment of the Motor

The Model 24 "His Master's Voice" motor can be adjusted for 100 to 130 volts, 200 to 260 volts, also for between 130 and 160 volts, if a special condenser of 3 mfds. is placed in series with the mains lead to the motor, and the motor is adjustable as for 260 volts. This exterior condenser will only be found if the instrument is working between 130 and 160 volts. The frequency range of the motor is 40 to 60 cycles. Mechanically, the H.M.V. Model 24 alternating current motor is much similar in operation to previous types of induction disc motors. There are, however, one or two circuit differences which should be observed when testing.

The Special Features of the H.M.V. Model 24 Motor

The circuit diagram is given in Fig. 1; note the illustration showing the connection of the special condenser for the 130 to 160-volt range.

The fixing of the coil assembly unit is somewhat different from other motors, only one magnet unit being employed.

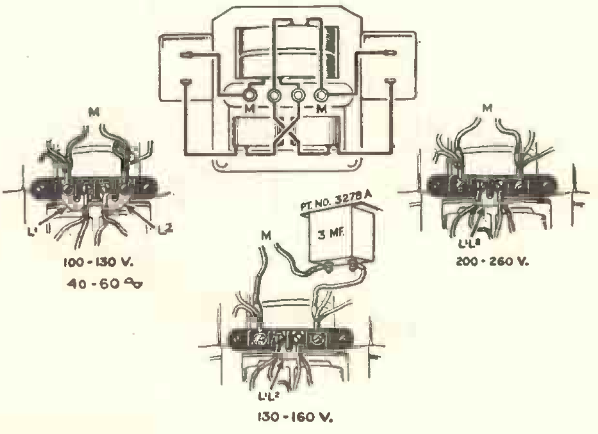


Fig. 1.—THE ELECTRICAL CONNECTIONS FOR THE H.M.V. TYPE 24 MOTOR FOR ALL VOLTAGES.

The Electrical Values of the Coils

See Fig. 2. The top coil LR is divided into two sections, the D.C. resistance of the two sections being 35 ohms each.

How to Measure the Top Coil

Check the resistance from lug 1 on condenser C.2 to voltage adjustment screw 3, and lug 1 on C.1. to voltage adjustment screw 3, when adjusted as shown in Fig. 2.

How to Measure the Lower Coil

Check the resistance from lug 2 on C.1 to screw 3, and for the other coil lug 2 on C.2 to screw 3. The D.C. resistance of the two lower coils LN.1 and LN.2 should be 1,100 ohms each.

How to take off the Condensers

Reference should be made to Fig. 2 when doing this, as otherwise a number of screws which are not necessary may be removed. Unsolder the leads to the condenser lugs and slack away screw a, shown in Fig. 2, and the distance piece on screw g in the case of condenser C.1.

Warning

Do not attempt to slack away screw g, or, in the case of condenser, to screw h from the back of the motor, as in both cases it is necessary to pass a screw from the back of the motor below the governor to the back of the magnet unit.

What to do if a Condenser Breaks Down

In the event of a condenser breaking down, in order to prevent the instrument being out of commission, any good make of Mansbridge condenser having a capacity of 2 mfds. may be installed temporarily by screwing on to the motor board, or some other convenient place, while replacement condensers are being procured.

How to take off the Magnet Unit

Remove screws a, b, c and d, but do not touch the two centre screws, as these are for the purpose of tightening the laminations of the magnet unit. No attempt should be made to rewind the coils, as it is a specialist's job. The whole magnet unit should be returned to the makers for replacement.

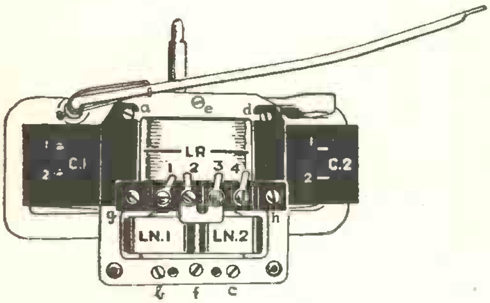


Fig. 2.—THE COILS AND CONDENSERS OF THE H.M.V. TYPE 24 MOTOR.

How to Remove the Governor on the 24 Motor

The governor is far more accessible on this type of motor than on earlier motors. Slack off the governor bearing screw k in Fig. 3 and also the governor bearing screw m. If the screw securing the bearing k is sufficiently slack, the k bearing will slip inwards towards the casting, so that the governor may be removed.

When replacing the k bearing it should be noted that this bearing is fitted with a slot which engages with the screw which secures the bearing into the casting. If this bearing is incorrectly adjusted, it may, of course, be fitted too tightly, the result being that a noisy governor may be produced.

How to Take Out the Induction Disc

Note that the induction disc has two grub screws securing it to the main spindle; these should be slacked away. Next slack away the screw r, which secures the gear wheel to the spindle. The spindle may then be withdrawn, slipping out of the worm wheel and rotor disc, which can then be lifted out of the frame of the motor.

It is very important that all grub screws should locate in the special dimples in the main spindle when reassembling, and that the steel ball in the lower main bearing should not be lost.

The Special Locating Plate of the 24 Motor (ss, Fig. 3)

It has been found that damage may be caused to the discs of induction disc motors if, when removing the turntable for any reason, the spindle is pulled upwards and the disc turned against the faces of the magnet pole.

The 24 motor is therefore fitted with a small metal stop secured by the screw ss, shown in Fig. 3. It is probable that this will not have to be adjusted if the motor is taken to pieces, but its function is to prevent the motor spindle rising so far that the upper face of the induction disc can engage with the lower face of the top pair of magnets.

Special Notes on Reassembling the H.M.V 24 Motor

Do not adjust the lower bearing screw, which is shown at t in Fig. 3. If, however, this has been disturbed, adjust this screw so that when the motor is the *right way up* the disc is in such a position between the magnet pole that it is free to rotate without touching either of them.

Do not forget the locating plate ss in Fig. 3. When replacing the gear wheel on the main spindle, note that the locking screw r should be on the top side; this is most important, otherwise the motor may not run correctly, due to the fact that the worm wheel on the main spindle is not correctly positioned with the gearing on the governor spindle.

What to do if the Motor will not Revolve when the Mains are Switched on

Examine the motor switch. Turn the

turntable gently to see if there is any mechanical jam. Check up the position of the rotor disc in the air gap between the magnets, if necessary adjusting the height of the disc by means of the lower bearing screw (see Fig. 3). If any stiffness is found, find out whether the stiffness is in the governor or in the main spindle by removing the governor. If it is found that the trouble is due to the governor or the relation between the governor and the main spindle, the position of the worm wheel on the main shaft should be checked, and also the stiffness or otherwise of the bearings of the governor. It is normal to have a small amount of lateral play in the governor bearings.

If the motor is found to be free mechanically, the electrical circuit, especially the mains supply, should be tested. This can be done at the motor pins or connecting screws by means of a lamp and lamp holder or a voltmeter.

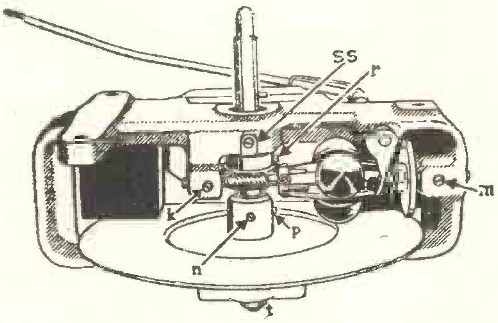


Fig. 3.—The Bearing Screws of the H.M.V. Type 24 Motor.

Where to Look if the Motor starts correctly but starts to slow down when the Needle is lowered on the Record (Lack of Power)

It is possible that the electric supply has altered in voltage; this sometimes happens in remote districts, also the motor may not be correctly adjusted.

This effect will also be produced if a fault has developed in one of the coils.

How to Spot a Faulty Motor Coil

Allow the motor to run for a few minutes, and then feel the temperature of the coils. They should be of the same temperature. A coil which is hotter than others suggests that the fault may lie in that coil, either due to a short-circuited turn in the coil or a possible short from the coil to the frame of the motor and from there to earth.

While this is being done it is well to check the electrical values of the other coils.

The Effect of a Broken-down Condenser

This will cause a weakness in the motor, but the presence of a short-circuited condenser or faulty condenser otherwise, may be checked by connecting across the terminals of each condenser in turn a small piece of wire. If a condenser can be short circuited without effecting the motor, that condenser may be faulty. If, on the other hand, the weakness is still further reduced when this is done, it is probable that the condenser is all right, and that the trouble must be looked for elsewhere.

The Effect of a Bent Regulator Lever

It sometimes happens that, due to carelessness or interference, the regulator lever, which passes from the motor to the screw in the motor board, for adjusting the speed of the motor has become bent, or possibly that it has actually slipped off the screw. This is an easy thing to do if for any reason the motor board has been lifted and replaced without it being noticed that this has happened. This will, of course, cause mechanical stiffness due to pressure being applied to the flange of the governor.

How to Cure Hum

This may be caused by a number of faults. A winding which is loose on the magnet unit core will cause hum, and can be cured by carefully wedging the coil with a small wooden wedge. When this is done, however, care must be taken that the edge of the coil does not protrude beyond the face of the magnet. All screws connecting the magnet unit should be tightened up, and those securing the magnet laminations should also be examined.

A motor which is loose on the motor board will also cause hum, and if it is fitted with bolt washers they should be examined. If no bolt washers are fitted between the motor and the motor board, these may be tried, but on inserting washers care should be taken that the height of the motor spindle above the top of the motor board is not disturbed unduly.

Where to look if the Motor is Mechanically Noisy

The disc may be touching the magnet laminations. Examine it to see if it is bent or if the lower bearing has become loose. As mentioned before, loose governor springs will cause mechanical noise. Excessive end play will cause mechanical noise, or end governor bearings which are too tight. The screws securing the bearings should be slacked away slightly while the motor is running and re-adjusted to the most silent position.

If the gearing on the main spindle is noisy it may be necessary to replace this as it may have become worn due to unsatisfactory lubrication or long service.

Motors which have had a great deal of use for some time may develop a slightly worn upper main bearing if lubrication has been neglected. If this is the case the motor should be returned to "His Master's Voice" for full treatment.

Fig. 4.—ADJUSTING THE BRUSH PRESSURE OF THE H.M.V. TYPE 25 MOTOR.

The Causes of Varying Speeds

Reference should be made to crazy governors in the first section of this article, and the whole governor assembly should be examined for tight bearings and any other reason for a hold-up in the revolution of the governor spindle.

The Effect of Unsuitable Lubrication

Unsuitable lubrication may cause sluggishness, especially if the motor has been started after some period in a cold room, due to the congealing of the lubricant. The special lubricants issued by "His Master's Voice" have been designed not to give these effects, in addition to the fact that they are absolutely clear from corrosive elements. Special attention should be paid to the lubrication of the small leather pad engaging with the governor flange.

H.M.V. DIRECT CURRENT MOTOR—TYPE 25

How to Recognise the Direct Current Motor—Type 25

This motor is entirely different from any other "His Master's Voice" motor, and will be recognised by the magnet coil and the square magnet frame, also by the fact that a commutator and brushes are fitted on the lower end of the main spindle.

Important Warning

Like the majority of direct current

motors, this motor is designed to operate on a voltage of 40 volts, a resistor being supplied to adjust any mains voltage to that value. *If this motor is operated on the bench, it must not, therefore, be connected directly to the mains.*

The Electrical Values of the Motor

Each field coil should be 35 ohms D.C. resistance. These should be measured with either the yellow or orange wires, as the case may be, completely disconnected from the terminal block. Do not forget to make a note to which screws they must be re-connected.

The total resistance of the motor measured at the terminal block, while the armature is slowly *rotated*, should be about 150 ohms. It will be found that there will be a slight variation as the motor is rotated, and a careful watch should be kept for a flicker of the meter, or a specially loud click if headphones and a battery are being used, which will indicate a faulty commutator section.

How to Locate a Faulty Commutator Section

Take out the armature, as described later, and, starting up the section with the black wire, press on each commutator section until the faulty section is located.

How to Remove the Field Coils and Magnet Frame

Reference should be made to Figs. 5, 6 and 7. First take off the brush assembly complete by removing the bolts which should secure the brushes to the field magnets (F in Fig. 7). Be careful not to disturb any insulating bushes or washers which may be found on the field frame, or, if these are disturbed, note where they should be put when replacing the brushes; also, be careful not to lose the spring washers and nuts. It is better to reassemble the entire brush assembly before putting it on one side, so that when it is wanted again it can be fixed up complete.

Next remove the orange and red wires from the terminal block (shown at J, Fig. 7). The field coils will be found secured by spring clips; these should be removed temporarily, and it will then be found possible to slide off the field magnet frame complete with the coil. In order to remove the coil, slide the coil away from the magnet.

What to Remember when Reassembling

One orange and one yellow wire should go to each brush lever, the other orange and yellow wires going to the terminals on the terminal plate. It is also very important to see that when the coils are replaced after renewal or repair the points on the coil, where the wires emerge from the coil, are near to the terminal blocks. Fig. 7 shows the position of these wires clearly.

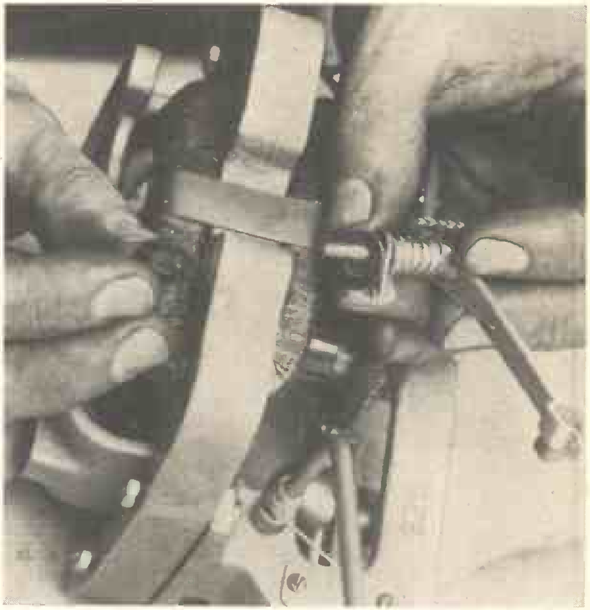


Fig. 5.—REMOVING BRUSH ASSEMBLY.
Note block insulating washers.

How to take away the Armature

First take off the magnet unit as described above, and then carefully loosen off the screw shown at G in Fig. 7, which secures the governor driving gear to the main spindle. The main spindle may then be withdrawn and the armature removed. If it is found necessary to remove the gear

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION • EXPERIMENTAL • THEORY

NEWNES COMPLETE WIRELESS

In This Part

PUSH-PUSH AMPLIFICATION

AUTOMATIC VOLUME CONTROL

TONE CONTROL

THE WESTINGHOUSE METAL RECTIFIER

1/-

Part 29

IN 32 WEEKLY PARTS

PART 29.

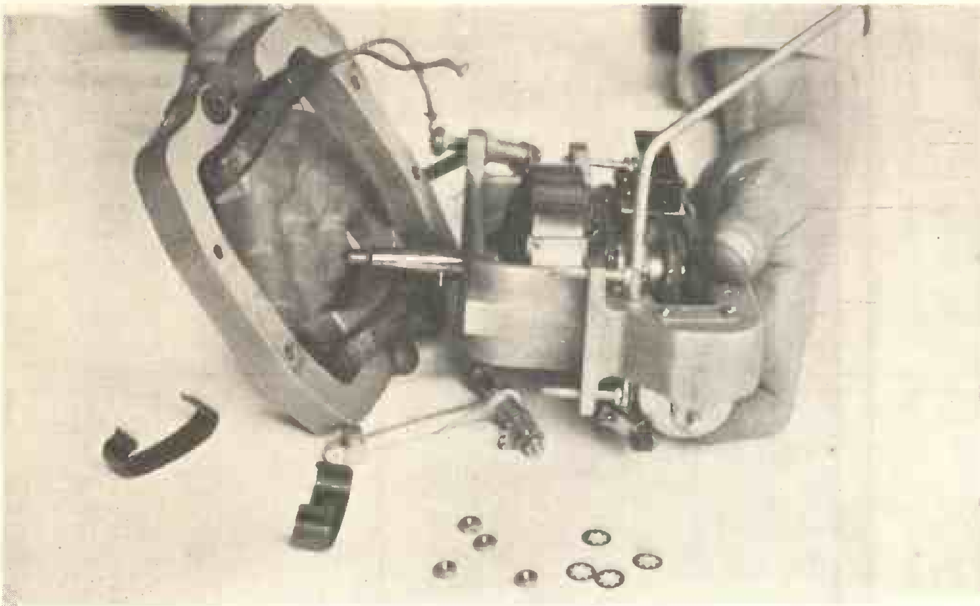


Fig. 6.—Removing the Magnet Unit.
Note the coil clips removed.

wheel from the armature, the grub screw must be entirely removed, when it will be found that the gear wheel can be taken right off. This is not necessary if it is merely required to take the spindle away from the armature and gear wheel. Be careful when reassembling that the grub screw locates correctly in the small dimple provided in the main shaft, so that it positions accurately up against the gearing of the governor drive.

What to do if the 25 Motor does not Revolve

Check as described above for any mechanical jam. Also check to see that the mains supply is correct, and that the resistance unit is correctly connected or adjusted. The mains voltage should also be tested. The correct voltage at the motor when the resistance is correctly adjusted should be 40 volts. The switch operated by the pick-up should also be examined to see whether it is functioning correctly. If the brushes are dirty or there is too much or insufficient pressure by them on to the armature, this may cause the motor to spark. A very dirty armature may also cause the motor to spark, in which case it should be cleaned with a strip of glass paper, *not emery paper*. Do not forget to remove small fragments of glass from the armature after cleaning. If one of the coils has become short circuited to earth, or the frame, or to the armature, this may cause the motor to stop.

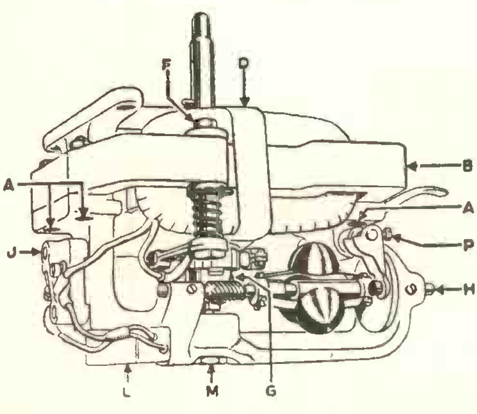


Fig. 7.—Details of the H.M.V. Type 25 Motor.

The Causes of an Overheated Motor—Overheated Resistor

If the fixed condenser which is connected across the brushes has become short circuited, the adjusting resistor may be found burnt out or overheated. If this is found, do not attempt to connect a new adjusting resistance before the condenser has been examined. The object of this condenser is to reduce interference by suppressing sparking between the brushes and the commutator.

Fig. 8.—The Anti-Sparking Condenser.

This is connected across the brushes to reduce interference by suppressing sparking between the brushes and the commutator.

Note.—If the motor will not revolve after reassembly, it may be due to the fact that the orange and yellow wires have not been correctly reconnected.

What to look for if the motor is Noisy Mechanically

Poor lubrication or the armature touching the field coils will cause a noisy motor, and, as stated before, a loose governor or any of the points in connection with governors which have been described before. If the bottom bearing of the motor is not correctly adjusted there may be noise due to the fact that the governor and fibre gear are not " fairly " engaged.

Electrical Interference by the Motor on Reproduction

This may be caused by sparking between the brushes and the commutator, or any intermittent wiring connection, possibly in the field coils or between the commutator segments and armature section. A slight defect in the small condenser may also cause crackling interference. If the contacts of the sliding resistance do not make firm connection with the coil of wire, this may also cause trouble, and a peculiar hum or spluttering sound might be caused if the motor frame is not correctly earthed. It is most important that the motor frame should be earthed whenever this motor is used, and, if it is necessary to examine the motor, this earthing wire should be carefully checked up.

THE B.T.H. HIGH SPEED SYNCHRONOUS MOTOR—TYPE Y.L.

This motor will be found in a number of radiograms, including the well-known McMichael Twin-speaker Radiogramophone.

How to Recognise the B.T.H. Type Y.L. Motor

The first thing that will be noticed is that there is no governor; secondly, it consists of a die cast frame having four magnet windings with the rotor of the motor rotating between them, actuating, through a spiral gear, a large fibre gear wheel, which is incorporated with a spring clutch device. A yellow paxolin-covered condenser will also be found between the top of the motor and the underside of the motor plate.

No speed regulator is supplied with this motor, as it is designed to run at exactly 78 revs. per minute on a 50-cycle alternating current supply.

The Electrical Characteristics of the B.T.H. Type Y.L. Motor

It will be noted that there is no winding that can be measured on the rotor of the motor, but that the field windings are brought out to four terminals. The resistance which should be found between these terminals is given below.

Note.—When the motor is adjusted for the high-voltage range two metal straps will be found connecting the two centre terminals; for testing the windings these should be removed. The resistance between the upper and lower terminals with the straps in position, that is, with the motor adjusted for the voltages of over 200 volts, is approximately 1,200 ohms. There should be no electrical readings between the bottom terminal and the top one, but the D.C. resistance should read approximately 1,000 ohms. The D.C. resistance between the top terminal and the one just below it should give no reading, and the reading between the two centre terminals with the links removed should give no reading.

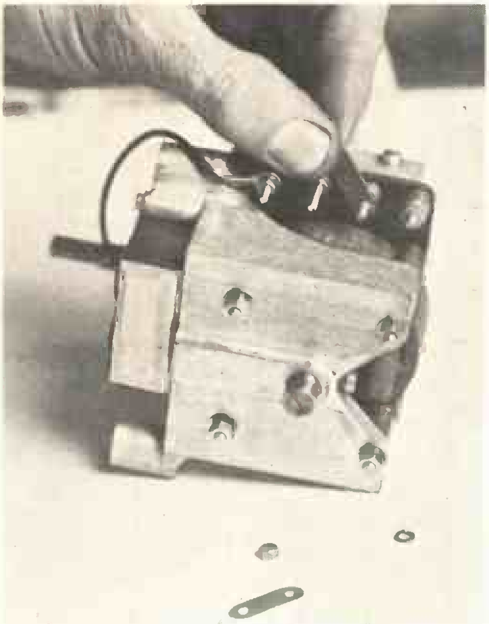


Fig. 9.—ADJUSTING THE B.T.H. TYPE Y.L. MOTOR FOR VOLTAGE.

When the motor is adjusted for the high-voltage range, two metal straps will be found connecting the two centre terminals.

The correct resistance between the two lugs of the condenser which are just visible below the frame should be about 1,200 ohms. A similar value should be found between the two other lugs immediately under the motor frame that is, between the bottom of the motor plate at the top of the motor frame itself.

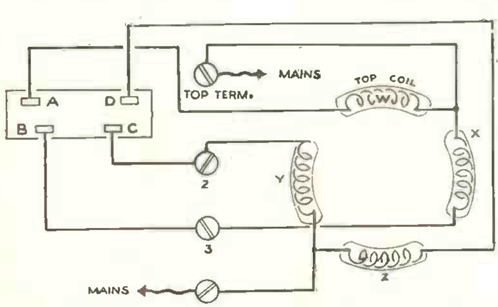


Fig. 10.—THE CONNECTIONS OF THE B.T.H. TYPE Y.L. MOTOR.

How to take out the Motor

Disconnect the two mains wires and also the wire connecting one side of the switch to the top terminal of the motor terminal board. The motor may now be removed by unscrewing the three screws securing the motor through rubber washers to the metal motor plate. Be very careful not to lose these rubber washers or any spacing washers which are present, making a careful note of the positions of the washers, so that the motor is returned correctly when it is reassembled on to the metal plate.

How to Measure the Resistance of Individual Coils (see Fig. 10)

THE TOP COIL (W).—Test from lug A of the condenser to the top terminal. The resistance of the coil should be 1,000 ohms approximately.

COIL (X).—Test from the top terminal to terminal 3 *with the links out of position;* the resistance should be 800 ohms.

COIL (Z).—Test from terminal 4 to condenser lug (D); the resistance should be 800 ohms.

COIL (Y).—Test from terminals 2 and 3 with the links out; the resistance should be nil (open circuit).

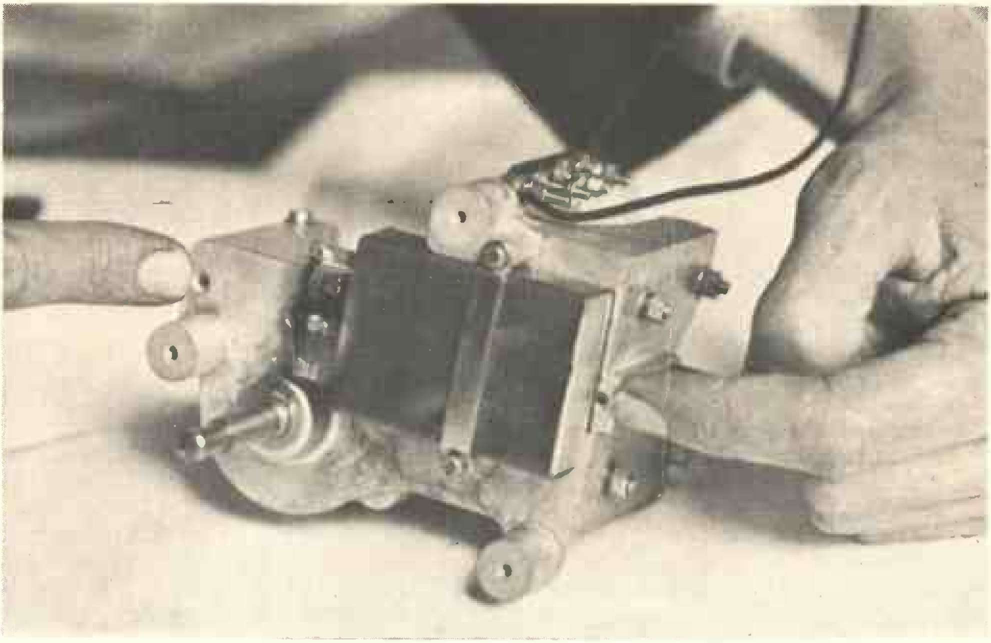


Fig. 11.—The Oiling Points for the End Bearings.

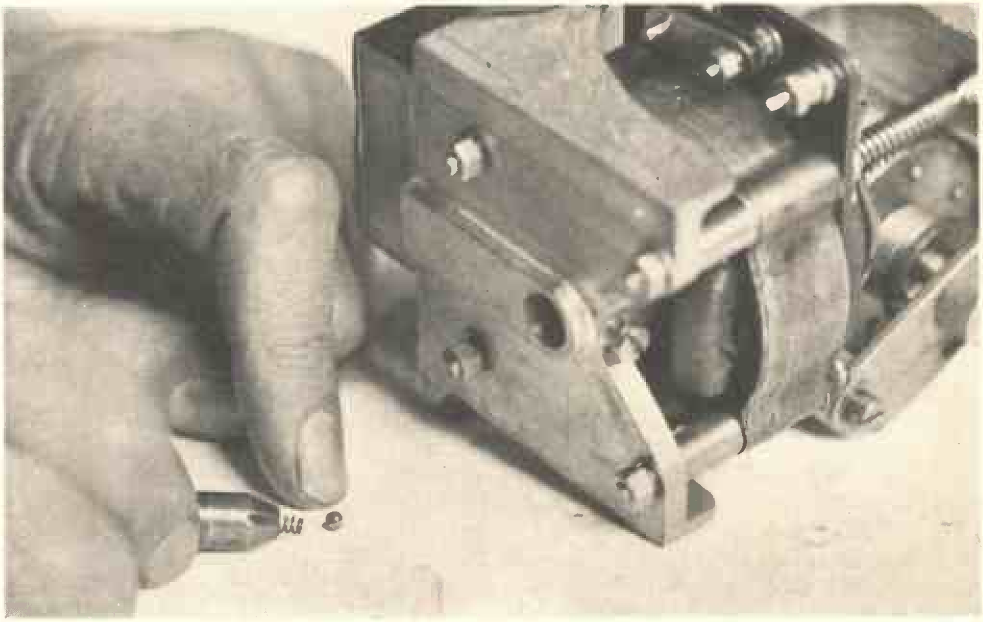


Fig. 12.—The Sprung End Bearing.

Showing how the ball bearing is kept in position by means of a spring. If rough running is experienced see that this spring is not broken.

Where to look if Difficulty is experienced with the Motor

Hum.—This may be caused by the bolt securing the laminations and magnet unit to the die cast frame being loose, or a certain purring may be heard if the gearing adjustments are not correct or have become worn.

Purring Sound.—Lack of lubrication will cause this, and the bearings should be examined to see that they are not too tight or that the spring in one of the bearings is not broken or dry of lubrication.

How the Bearings are Arranged

The bearings of the B.T.H. Type Y.L. motor are somewhat different to the ordinary run of motor bearings. The bearing itself consists of a hollow phosphor bronze bush, secured in position in either end of the die cast frame of the motor by means of a locking screw, which, in the case of the end nearest the main spindle, is on the side of the frame, and in the case of the end nearest the magnet unit, on the under side; it will be noticed that both these bearings have slots in them, and, when reassembling or when inspecting, it should be seen that one of these slots is uppermost, so that oil sent down through the oil hole can find its way through one of the slots down towards the point where the shaft enters the bearing, thus lubricating the bearing. A dry bearing may be caused by the fact that though oil has been poured through the oil hole, the bearing has been rotated either by accident or deliberately, so that the oil is unable to

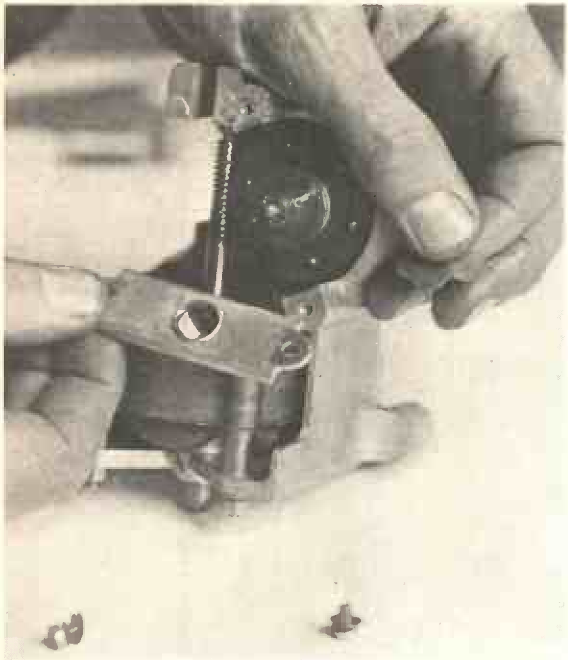


Fig. 13.—Removing the Lever Bearing.
Note the small shims in the left hand.

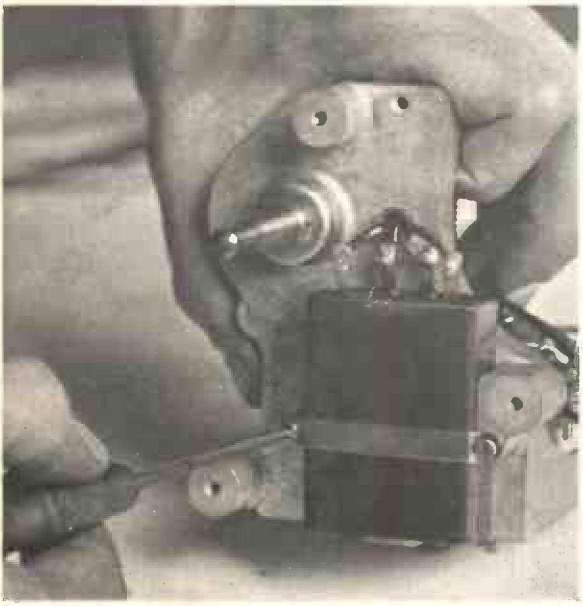


Fig. 14.—Removing the Condenser.
The condenser should be suspected if the motor is found running very slowly or weakly.

penetrate down through the slots, thus causing a dry bearing.

A special feature of the bearings of the B.T.H. Y.L. motor is that, unlike most motor bearings, although they are supplied with the usual steel balls found in most gramophone motors, in the case of the bearing nearest the magnet unit, the ball is kept in position by means of a spring. If rough running is found, this spring should be examined to see that it is not broken, or that the ball has not become crushed or broken.

Fig. 15.—The Spring Clutch Assembly.

The Best Way to Adjust the Bearings

It is better not to move the bearing nearest the magnet unit, but to do any adjustment of the bearings, if they are found to be running roughly, by means of the bearing located in the slot of the die-cast frame of the motor that is nearest to the end of the main spindle and gear wheel.

It will be found that on slacking away the set screws at the side of the casting, this bearing can be rotated or pulled inwards or outwards slightly to procure the quietest running position. The normal position of the bearings should be with slightly less than a $\frac{1}{4}$ inch of the slotted tapered end protruding beyond the inside edge

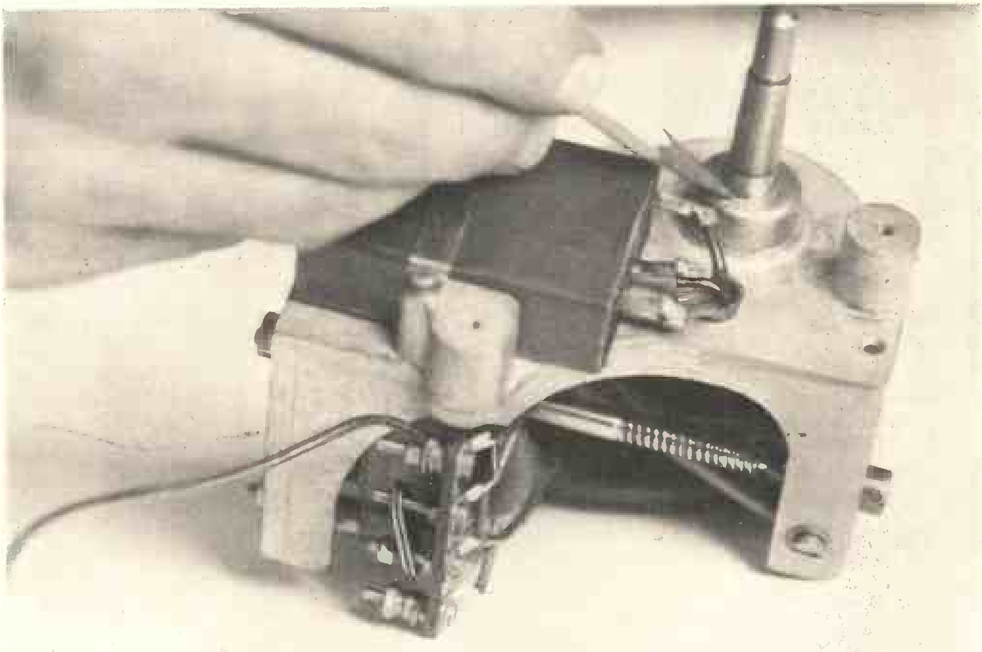


Fig. 16.—Indicating the Oiling Point of the Upper Main Bearing Spindle.

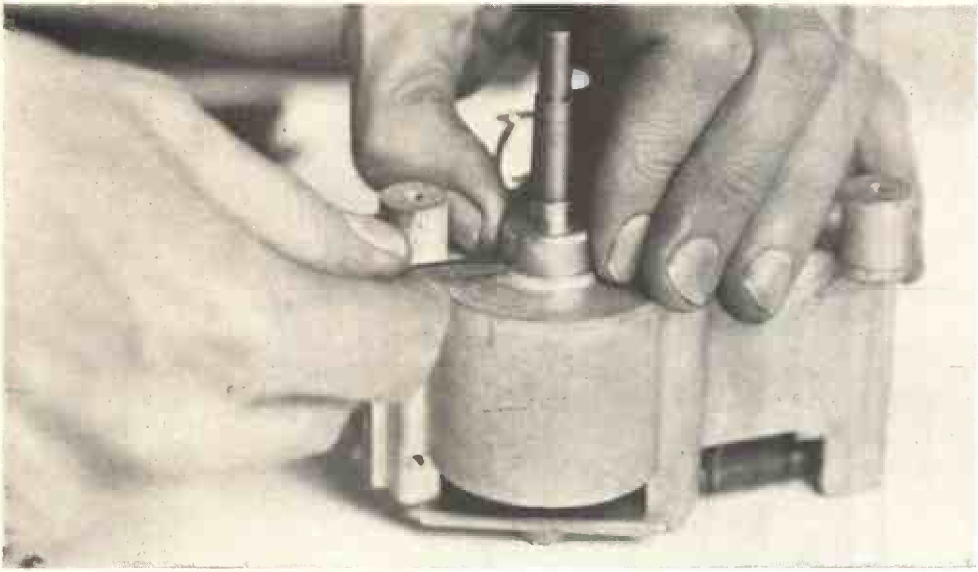


Fig. 17.—Removing the Felt Oiling Pad

The upper bearing lubrication of the mains spindle is supplied by means of a circular felt pad. This should be examined to see whether it is dry.

Fig. 18.—Removing the Rotor.

First remove the phosphor bronze bearing. Then entirely remove the locking screw, so that the rotor may be withdrawn by sliding the spindle down the slot in the die-cast frame of the motor.

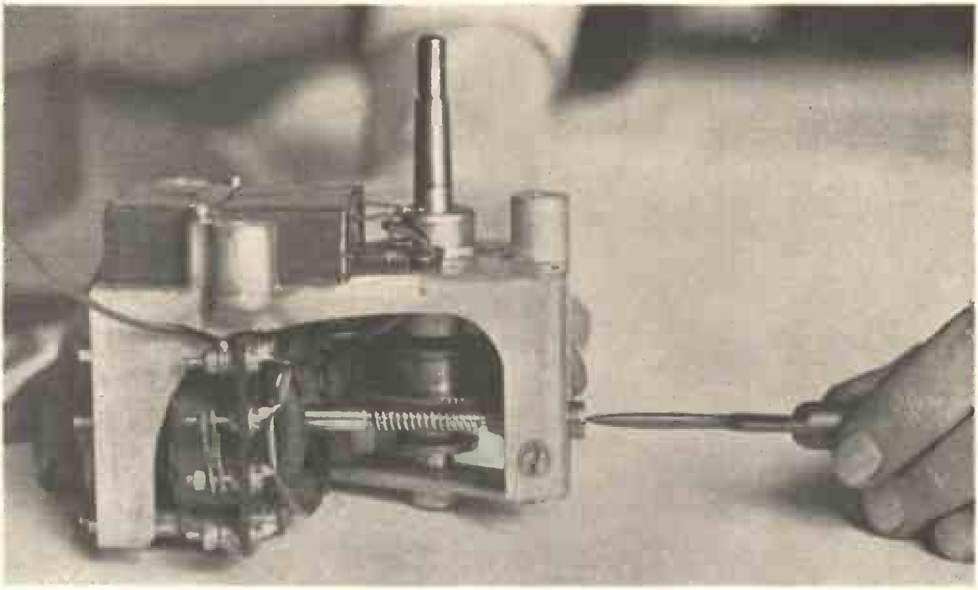


Fig. 19.—Adjusting the Rotor Spindle Bearing.

of the die-cast frame. It should be borne in mind that it is most important, when adjusting for quiet running, that the motor should be the right way up, but it will be noted that the spindle has a certain amount of vertical play which is common to most types of gramophone motor.

The Effect of a Broken-down Condenser

The condenser should be suspected if the motor is found running very slowly or weakly. This is usually indicated by a dragging up of the speed on loud record passages or inability to play loud passages, especially on the outer edge of the record. At this point, however, a careful examination should be made of the motor to see that there is no mechanical roughness, due to worn bearings or lack of lubrication, before the condenser is actually suspected. If, however, the condenser is suspect, the test should be made between contact B and C or A and B. If there is a short circuit here the condenser should be exchanged. If the motor will not revolve at all after the mains have been switched on and the motor is found to be clear of mechanical jam, a short circuit may be found between the condenser contacts A and B, accompanied possibly by signs of a heated coil. When the motor is running normally, the coils do not show this sign of warming up.

A Quick Check of the Condenser and Motor Coils (Straps in position for 200 v.)

Resistance measurement between contact A and B, 1,100 ohms.

Resistance measurement between contact B and C, short circuit.

Resistance measurement between contact D and C, 1,100 ohms.

Resistance measurement between contact A and D, 1,300 ohms.

When making these tests, reference should be made to Fig. 10. These tests are given for the motor, as connected, for the high-voltage range; that is, with the two metal straps connected between the two centre terminals and the mains connected to the two outer terminals.

How to take out the Main Lower Bearing

The main spindle assembly can be dismantled by removing the two screws which secure the lower metal bracket in which the lower main bearing is situated, taking great care not to lose the spring washers or metal washers on these screws. The lower bearing bracket may then be removed, but care should be taken to see that the small metal ball which may be found either in the lower bearing itself or adhering to the lower end of the mains spindle is not lost or damaged. This bearing should be carefully examined for a damaged steel ball and for adequate lubrication, which should be in the form of a suitable grease.

The Clutch Assembly

The mains spindle will be found to be connected to the gear wheel by means of a spring clutch assembly. The object of this clutch is to prevent a severe strain being placed on the gearing or the main rotor spindle if the turntable is suddenly stopped or turned violently. It is not likely that this clutch assembly will give any difficulty. If, however, it is necessary to replace the gear wheel, it is advisable to send the whole mains spindle, clutch assembly and gear wheel back for repair or replacement, as the installation of this clutch against the spring is not easy.

The Lubrication of the Mains Spindle

The upper bearing lubrication of the mains spindle is supplied by means of a circular felt pad, which is protected by a small metal cowl. This should be examined to see whether it is dry, and if so, the cowl may be gently levered off, making it possible to remove the pad and soak it in some suitable oil or replace it if necessary. It is essential when levering off the small metal cowl that it should not be damaged in any way.

How to take out the Main Rotor Assembly

First remove the phosphor bronze bearing, which is situated in the slot in die cast frame of the motor nearest the gearing. Then entirely remove the locking screw situated in the side of the mains frame of the motor, so that the rotor may be withdrawn and taken out by means of sliding the spindle down the slot in the die-cast frame of the motor. When this is done the greatest possible care should be taken to see that the gearing of the spindle and the spiral gear cut on it are not damaged in any way. If they are, on reassembling, rough running may result, or possible damage to the fibre gear wheel on the mains spindle. The rotor should be put in a safe place where it cannot possibly be damaged.

How to Remove the Magnet Unit

The wires to the condenser should be unsoldered from the lugs on the condenser, careful note being made on each wire as to its position. Incorrect restoration of these wires may result in unsatisfactory running of the motor. These wires may now be pulled through the systoflex sleeving, which protects them from the metal die-cast frame of the motor, and, on unslacking the third bolt at the end of the motor, the magnet unit may be withdrawn complete.

THE WESTINGHOUSE METAL RECTIFIER

By D. ASHBY, A.C.G.I., B.Sc., D.I.C.

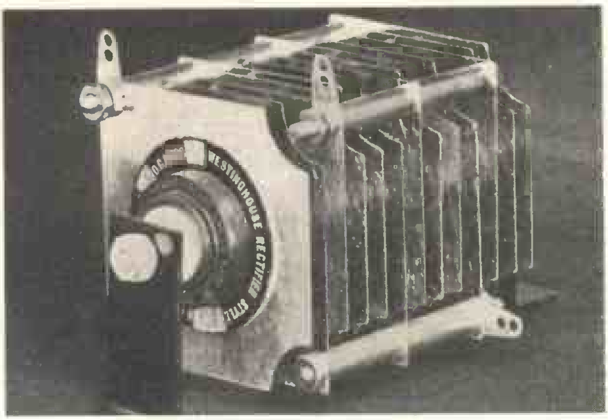


Fig. 1.—A TYPICAL "WESTINGHOUSE" METAL RECTIFIER. THE L.T.—4.

THE Westinghouse metal rectifier was introduced to the radio industry in 1927 as a means of converting alternating current from the local supply mains into unidirectional current. As the rectifier had proved entirely satisfactory during the previous year, when it had been extensively used for battery charging and in various circuits connected with railway signalling, the increasing demand for a reliable and efficient rectifier for operating a mains-driven receiver opened a wide market in which the Westinghouse rectifier is now a standard component.

The Action of the Westinghouse Rectifier

The action of the Westinghouse rectifier depends on the fact that the electrical resistance at the junction of various metals and metallic compounds differs in accordance with the direction in which the measurement is made. Copper is the metal generally employed, which, in conjunction with cuprous oxide (the red oxide of copper), forms a dependable and efficient rectifier which is not very expensive to produce. The electrical resistance, measured in the copper-copper oxide direction, is many times that in the opposite sense, the ratio of resistances being of the order of 1,000 to 1.

The precise action is not fully understood, but may depend on the supposition that a large number of free electrons exist in a mass of metallic copper, while the proportion in cuprous oxide is minute. Thus a positive potential applied to the oxide mass will produce an electron flow from the copper into the oxide in the same manner as in a diode valve in which the anode is represented by the cuprous oxide.

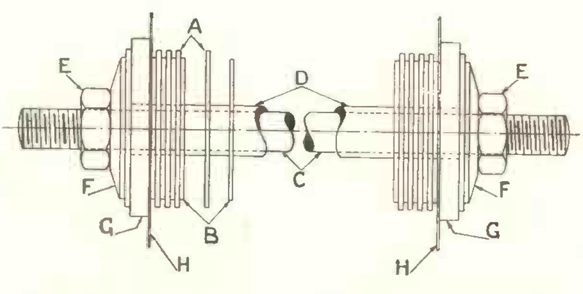


Fig. 2.—THIS SHOWS HOW THE WESTINGHOUSE METAL RECTIFIER IS CONSTRUCTED.

Not Dependent on Temperature Difference

Unlike the thermionic valve, however, the action does not in any way depend on a temperature difference between the electrodes. When a negative potential is applied to the oxide the passage of electrons from the oxide to the copper is very small and the resultant back current is minute.

Long Life

As the action of the rectifier depends on electronic considerations, no chemical change occurring, it would appear that its life is not restricted in any way. This is confirmed in practice, as several Westinghouse rectifiers have been in continuous service since 1926 and are still giving excellent performance, while tests, under widely varying conditions, carried out by the manufacturers, for 60,000 hours continuous operation, indicate that no change in characteristic occurs.

Excessive heating will ultimately destroy a Westinghouse rectifier, as is the case with the majority of electrical apparatus. Any excess current drawn from the rectifier will cause additional internal heating, which, if the overload is maintained, may produce a permanent change in characteristic. An increase in the reverse voltage will produce a greater leakage current, which after a point, will increase at a greater rate than the corresponding voltage, in a similar manner to the magnetising current of a transformer which is operated at an increasing flux density. Heating can also be due to insufficient ventilation or to an excessive ambient temperature.

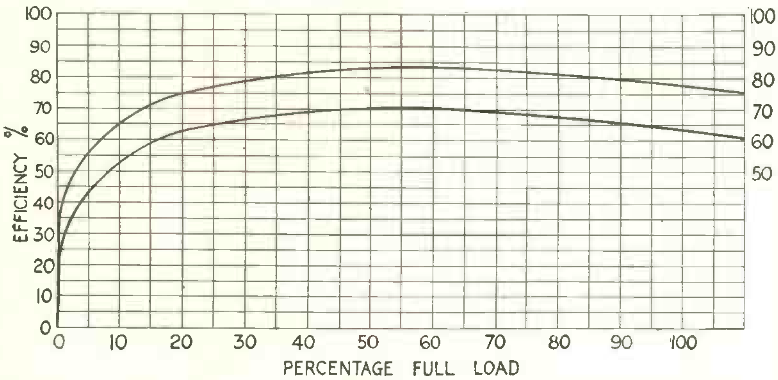


Fig. 3.—The Top Curve shows the True Power Efficiency, while the Lower Curve shows the Effective Efficiency for Battery-Charging.

The Rectifier cannot Distort the Wave Form

The Westinghouse rectifier cannot produce any electro-magnetic radiation or distort the wave form in any way, and may be compared with a non-inductive resistance. The capacity is so infinitesimal that it may be ignored, even in connection with the operation of sensitive measuring instruments, at anything less than radio frequencies. The smoothing circuit required is no more elaborate than for a valve type rectifier, and no difficulties occur in smoothing the output for operating ultra short-wave transmitters and receivers. The efficiency is maintained at a high value over an exceptionally wide range of loading, which is of considerable importance in large plants where the range of load variation is extensive.

Efficiency

Reference to Fig. 3 will show that the efficiency is above 70 per cent. from about one-sixth full load upwards, the value being the ratio of the power output to power input as measured on a wattmeter. This is the true efficiency figure, but in various circuits, in particular for battery charging purposes, the *effective* power output is the product of the chemical values of current and voltage as measured by moving-coil instruments, the lower curve showing the effective efficiency calculated in this manner.

As there is a certain amount of ripple in the circuit, the " mean " voltage and current values are less than the corresponding " RMS " figures, this reduction producing an optimum effective efficiency of any single-phase static rectifier of about 80 per cent., measured as the ratio of the mean volt-amperes in the D.C. circuit to the input RMS volt-amperes.

How the Oxide Layer is Produced on the Copper Elements

The oxide layer is produced on the copper elements, which are in the form of discs about $\frac{1}{32}$ inch thick, and in various diameters up to $1\frac{1}{2}$ inches, by heating them to a high temperature in electric furnaces and then allowing the elements to cool. The copper elements are blanked out of sheet and a central hole is punched in each for fixing purposes. In the heating processes the copper elements are mounted on rods in pairs, so arranged that a layer of oxide is produced on one side only of each disc, the other side being practically untarnished.

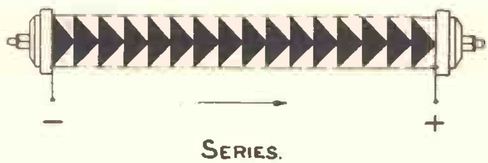


Fig. 4A.—TYPICAL ASSEMBLIES OF RECTIFIER ELEMENTS.

Series assembly.

Auxiliaries that are Required

Various auxiliaries are necessary to produce a rectifier of high efficiency, although these play no part in the actual rectification. The surface of the cuprous oxide is microscopically uneven, and special arrangements are necessary in order to reduce the contact resistance between this and the next component. The method generally adopted is to clamp the copper element under considerable pressure against some soft metal such as lead, a thin disc being placed either side of each copper element.

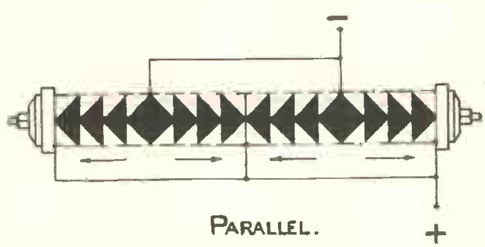


Fig. 4B.—TYPICAL ASSEMBLIES OF RECTIFIER ELEMENTS.

Parallel assembly.

A Typical Assembly

Fig. 2 shows a typical assembly. A number of copper discs A and their associated lead discs B are assembled on a spindle C, from which they are insulated by a sleeve D, and are tightly clamped by means of the nuts EE and spring washers FF, insulated from the copper elements by means of bakelite mouldings GG. External connections are made to the fins HH at each end, the assembly forming a half wave rectifier.

How the Maximum Power is Obtained

In order to obtain the maximum power from a Westinghouse rectifier, cooling vanes are mounted at intervals along the clamping spindle to dissipate the small amount of heat produced due to the internal losses. The full advantage of the increased cooling surface offered by the vanes is not obtained if they are close together, as layers of heated air form on their surface. This is overcome by the use of spacing discs, placed between successive vanes, to increase the distance between them, so the air may pass without restriction. It is most important that the rectifier is so mounted that the vanes are vertical, otherwise their heat dissipating power is considerably reduced as the air will not be able to circulate freely.

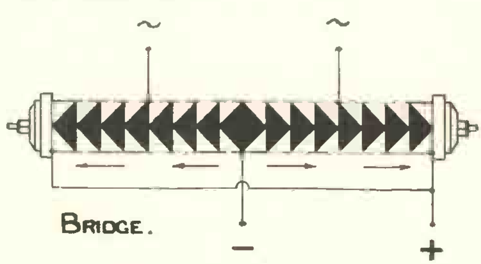


Fig. 4C.—TYPICAL ASSEMBLIES OF RECTIFIER ELEMENTS.

Bridge assembly.

Rectifier used for Battery Charging

The complete assembly of rectifier elements and associated components forms a very rigid unit which will stand up to any amount of vibration. If the rectifier assembly is to be

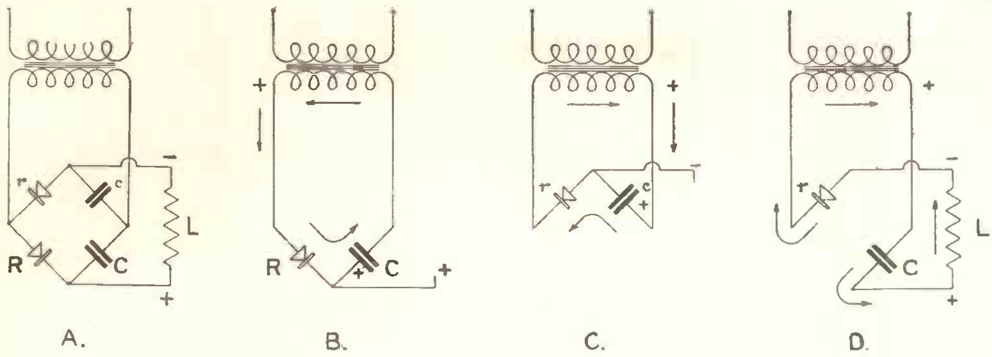


Fig. 5.—The Voltage Doubler Circuit.

A shows that the circuit is similar to the bridge circuit in which two sections of the rectifier are replaced by condensers C and *c*. B shows that during one half cycle the condenser C will be charged up. C shows the successive half cycle, and D the current returning through the rectifier.

used for battery charging, it is dipped in a special cellulose enamel to prevent corrosion and to resist the attack of the acid fumes.

How the Elements are Assembled

Each copper element is capable of carrying a certain current in the conducting direction and of withstanding a certain reverse voltage in the non-conducting direction. Thus a large number of elements are connected in series for high-voltage outputs, the highest voltage reached being 100,000 at 100 milliamperes for electrostatic precipitation, while currents up to 1,200 amperes at 6 volts have been obtained by connecting a large number of elements in parallel. Figs. 4A, 4B and 4C show the way in which the elements are assembled and the external connections made in order to produce series, parallel or multiple circuits, the arrow head indicating the direction in which current can flow.

Highest Output Obtainable

It has not been found practicable to produce elements larger than 1½ inches diameter, a very large number of these being employed in a high-capacity rectifier. This restricts the output of a Westinghouse rectifier to about 10 kilowatts, above which the enormous number of components necessitates a very costly and bulky structure. A 10-kilowatt rectifier will contain over a quarter of a million hand-assembled components, exclusive of framework, wiring or auxiliary gear.

Using the Rectifier for Wireless Purposes

The most important use of the Westinghouse metal rectifier in connection with radio is for the anode supply to all-mains receivers, in which the voltage doubler circuit is utilised. This provides an economical method of obtaining a high voltage at a low current, and has the advantage that the short-circuit current is limited due to the impedance of a series condenser.

The Voltage Doubler Circuit

The circuit, as will be seen by referring to Fig. 5, A, is similar to the bridge circuit in which two sections of the rectifier are replaced by condensers C and *c*. During one half cycle the condenser C will be charged up by the transformer current passing through the rectifier R, the lower plate being charged positive (see Fig. 5, B).

In the successive half cycle (Fig. 5, C) a similar charging circuit is provided for condenser *c* in series with rectifier *r*, the two capacities being in series. Current through the D.C. circuit L is provided by the transformer secondary winding, in series with condenser C, which was charged during the previous half cycle, returning through rectifier *r* as shown in Fig. 5, D. The arrangement is virtually a current-halver, two parallel circuits being provided.

The Bridge Circuit

The bridge circuit is generally adopted for charging filament batteries, a step-down transformer being necessary to reduce the voltage to an economical value. This arrangement of the rectifier elements is also used for operating moving-coil instruments for measuring alternating currents and pressures. The advantage of robustness and linear scale shape possessed by the moving-coil instrument is thus available for A.C. measurements, the power consumption being only 5 milliwatts or less.

Special Rectifier for Radio Frequency Measurements

A special rectifier with copper elements about $\frac{1}{32}$ inch diameter is being developed for radio frequency measurements, the capacity being insufficient to introduce any appreciable error. A rectifier of this nature is being produced under the trade name of "Westector" for use as a radio detector, its chief use being in the intermediate stage of a superheterodyne receiver to replace the double-diode valve, and in connection with various automatic volume control circuits.

The "Westector" is about the size of a grid leak, and may be incorporated in the wiring, thus overcoming the capacity to earth, a problem which precludes the use of valves in various circuits owing to their high cathode-heater capacity. Its characteristic is a straight line with no saturation point, hence no overloading can occur in the detector stage.

CONNECTORS, PLUGS AND SWITCHES

WHEN choosing battery tags and connectors, choice should fall on those with a minimum of exposed metal, easy to detach and having a cover or grip to hold the braiding or rubber covering.

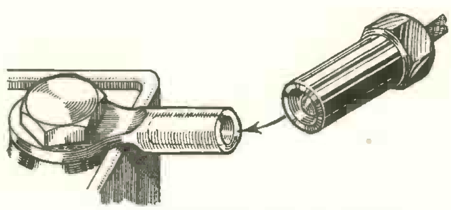


Fig. 1.—A USEFUL ACCUMULATOR CONNECTOR.

One excellent example is the Belling-Lee—shown in Fig. 1. Lead-plated eye-sockets of unequal size are permanently clamped under the battery terminal nuts; connections are made as required by pushing the insulated plugs into the sockets. In no circumstances can a wrong connection be made nor can a short-circuit occur should loose wires foul the battery leads.

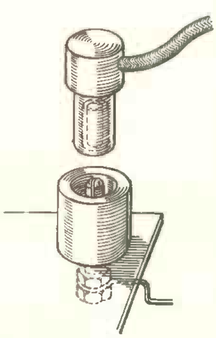


Fig. 2.—A SHROUDED PLUG AND SOCKET.

Specially for use with eliminators and mains sets.

Plugs and Sockets

These are very handy and neat, and a shrouded fully insulated type is shown in Fig. 2. An insulated twin non-reversible type for mains use is shown in Fig. 3. Using accessories such as these often prevents a short circuit with consequent damage to components. The cost is trivial and their use is far more workmanlike than looping wires around exposed terminals.

Switches

Roughly, there are three types of switches in general use, the rotary, the push-pull, and the lever or knife type.

In addition there are in all the above groups switches suited only to low currents and battery work, others with a quick make and break movement and switches specially for mains use.

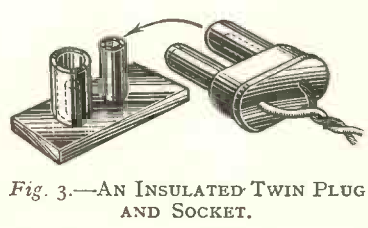


Fig. 3.—AN INSULATED TWIN PLUG AND SOCKET.

Non-reversible and fully shrouded.

PUSH-PUSH AMPLIFICATION

By ALAN POLLOCK

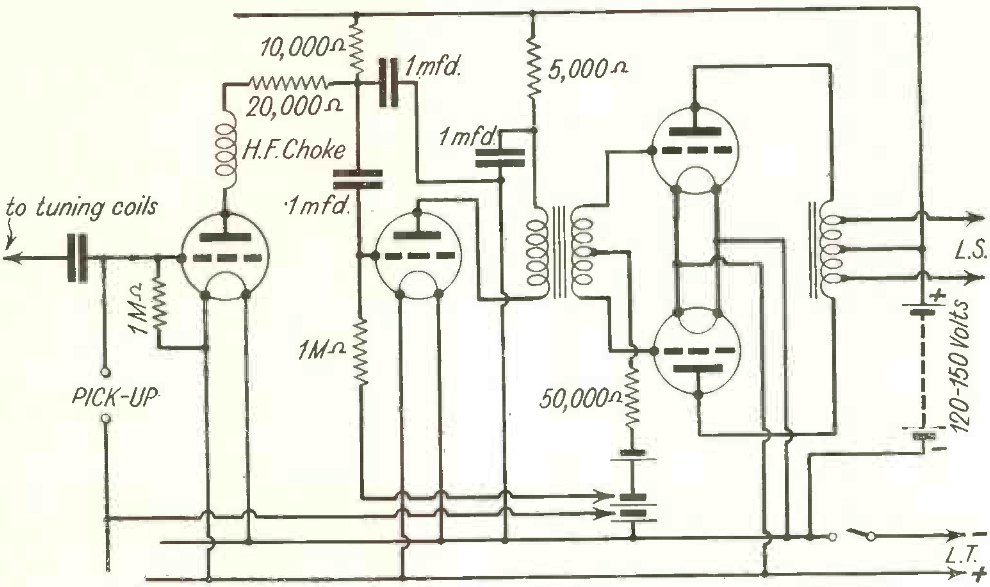


Fig. 1.—Typical Circuit Diagram of a Det. 2 L.F. Receiver using Quiescent Push-Pull. The tuning circuit has been omitted for the sake of clearness.

CAN a battery set ever compare in performance with a really good mains set? If performance means sensitivity and selectivity, the answer is "yes." If, however, the term includes quality of reproduction and "punch," or, as makers put it, "maximum undistorted output," the answer until recently was "no."

The battery user, after a period of neglect, has been blessed with a number of improvements, of which the most important are battery superhets, sensitive and cheap permanent magnet moving-coil speakers, and high efficiency pentode valves. He was prevented, however, from reaching equality with a mains user in the matter of "punch." To get an undistorted output of 1 watt, which is somewhat less than that of the average domestic mains set, 25 milliamperes have to be taken out of the H.T. battery all the time. Large output thus meant excessive expense in battery replacement.

Push-push amplification is not new; it has been used for years in radio transmission and for some considerable time in American battery sets, but until recently no suitable components for push-push circuits were available in this country, and the great advantages of the system could not be extended to the constructor public.

Circuit of a Q.P.P. Output Stage

Fig. 2 shows the circuit of a Q.P.P. output stage. Q.P.P. stands for Quiescent Push-Pull, and is used to describe the circuit in which two output valves, pentode or triode, are biassed down to the bend of their characteristics. The combined current passed by the output stage thus biassed is very small indeed compared with the current passed by each valve individually when used in a straight circuit, or, as the saying is, as Class A amplifiers. Thus two large pentodes in

Q.P.P. take about 4 milliamperes, instead of the normal current of 25 milliamperes for each valve. The term push-push includes the so-called Class B amplification in which specially designed high amplification factor triodes work in push-pull in the output with a small negative or zero current of 50 milliamperes. This is obviously far beyond the capacity of even the largest H.T. battery. By using the same two pentodes in Q.P.P., the total working current will average at 8 milliamperes. The difference is colossal, but is quite easily explained.

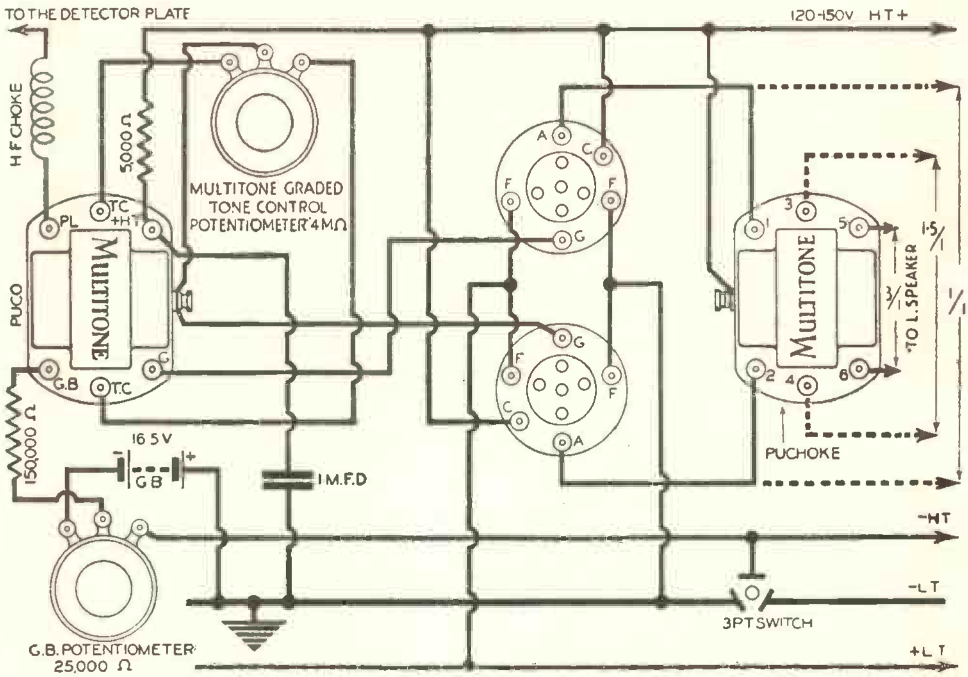


Fig. 2.—Circuit of a Quiescent Push-Pull Output Stage.

It is quite easy to build a Q.P.P. amplifier or to convert an existing receiver to Q.P.P., but specially designed components must be used. It is of interest to battery users only, and it would be a waste of time to attempt to run a set with Q.P.P. output stage off eliminators.

grid bias. The valves then pass grid current, and are fed from specially designed step-down input transformers. Class B valves have not yet been released in this country, so that we need only consider Q.P.P.

Figures the Battery User should Consider

A battery user may well ask why should he go to the complication of doubling his output valves, of employing specially designed components, of placing resistance here, or a condenser there, just in order to call his set Q.P.P. But figures speak for themselves. In order to get the output of a mains receiver, the battery users must employ two pentodes passing a total

Essential Difference between a Single Output Valve and a Q.P.P. Output Stage

A single output valve passes *all the time* the plate current necessary to deal with the loudest signal transmitted, while a Q.P.P. output stage, in addition to a very small quiescent current, drains the battery in proportion to the strength of the sound radiated and only while the sound lasts.

How the Saving is brought about

It must be understood that the quiescent current does not represent the current consumption of the output stage, which will fluctuate with the signal between very wide limits. The saving is, therefore, brought about by making the current consumed proportional to the sound you get out of the speaker.

BUILDING A Q.P.P. AMPLIFIER

It is quite easy to build a Q.P.P. amplifier, or to convert an existing receiver to Q.P.P., but specially designed components must be used. The input transformer has to be of much higher ratio than is commonly employed, for the step-up to the grid of each valve is half that of the total step-up, while the grid swing necessary to load the output stage is double that required for each valve used singly.

The Input Transformer

The input transformer shown in Fig. 2 is a tone-control instrument, and allows in conjunction with a high resistance potentiometer the tonal balance of the reproduction to be varied between very wide limits, from all bass no treble, to all treble no bass. This feature is of considerable importance in Q.P.P. circuits; the volume that can be obtained is much increased, consequently various defects in the quality of reproduction will become more obvious. For instance, booming in moving-coil speakers is liable to make speech very unpleasant indeed when the output is round about 1½ watts. Similarly, needle-scratch and shrillness in gramophone records is often intolerable at big volumes.

The Output Choke

The output choke used is also a specially designed Q.P.P. component. On account of large fluctuations of plate current, the resistance of the output choke or transformer must be much lower than that of normal push-pull output components.

When an Output Choke is not Needed

New moving-coil loud speakers can now be bought with output transformers specially wound for any representative type of valves in Q.P.P. In this case the output choke will not be necessary, for the transformer terminals can be connected directly to H.T.+ and to the anodes of the output valves.

CONVERTING AN EXISTING RECEIVER TO Q.P.P.

For those desiring to convert existing receivers to Q.P.P., the best plan is to add another valve holder to the set and to buy an output valve similar to the one already used. There are no difficulties in this connection when the valves employed are pentodes. If, on the other hand, the existing output is triode, there are two cases to consider.

Case 1.—Sets having an Intermediate L.F. Stage following the Detector

This case can be dealt with quite simply, the centre-tapped transformer being connected in the plate circuit of the first L.F. valve, and any type of triode valves can be used in the output.

Case 2.—No Intermediate L.F. Stage

Only the smallest triode output valves can then be used, such as the Marconi LP2, and 150 volts H.T. is strongly recommended.

Triodes, such as P2 of the same make, cannot be fully loaded without an intermediate stage. Generally speaking, if really large output combined with maximum sensitivity is desired, pentode output should be used.

Suitable Pentode Valves for Q.P.P.

For the purposes of Q.P.P., PENTODES can be divided into two classes :—

Class 1, of which Marconi PT2 and Mullard PM22A are examples, will give a maximum output of about 1 watt, while those in Class 2, which include Mullard PM22, Cossor 220PT and Mazda Pen 220A, will give greater output, but are less sensitive. That is to say, greater grid swing will be required to load them.

Fig. 3 shows outputs to be obtained with Marconi PT2 Q.P.P. stage in various working conditions.

Q.P.P. is only for Battery Sets

It is important to note that Q.P.P. need be of interest to battery users only. Constructors proposing to run their sets off eliminators will be wasting their time in building Q.P.P. sets, for no A.C. eliminator other than those employing mercury vapour rectifiers and low-resistance smoothing equipment will give good results, while even D.C. eliminators have to be specially designed foı the purpose.

Further, the mains user is not in any way limited in his H.T. current, providing he buys a sufficiently large eliminator. He can consequently run a large pentode or two pentodes in parallel or normal push-pull and get all the output he may wish.

The big saving in H.T. current consumption resulting from the use of Q.P.P. circuits does not change the fundamental fact that it is cheapeı in the long run to use double capacity batteries in preference to those of standard capacity.

Type of H.T. Battery Most Suitable

H.T. batteries are now available specially for Q.P.P. combined with grid bias batteries. It is suggested that these be used in all cases where biassing with a potentiometer is employed, as the grid bias volts will drop with use, and, even if a separate grid bias battery is used, it will have to be renewed together with the H.T. battery. If, on the other hand, the direct method of biassing is used, a separate grid bias battery is recommended.

Correct Bias is of Vital Importance

Biassing without an ammeter seems at first to be a difficult matter. It has been found, however, that by using a potentiometer as shown in Fig. 2, the biassing procedure becomes quite simple; it must be emphasised, however, that biassing is the most important adjustment in the Q.P.P. circuit and that the full advantages of the system will not be realised unless the valves have sufficient bias to pass only a very small current.

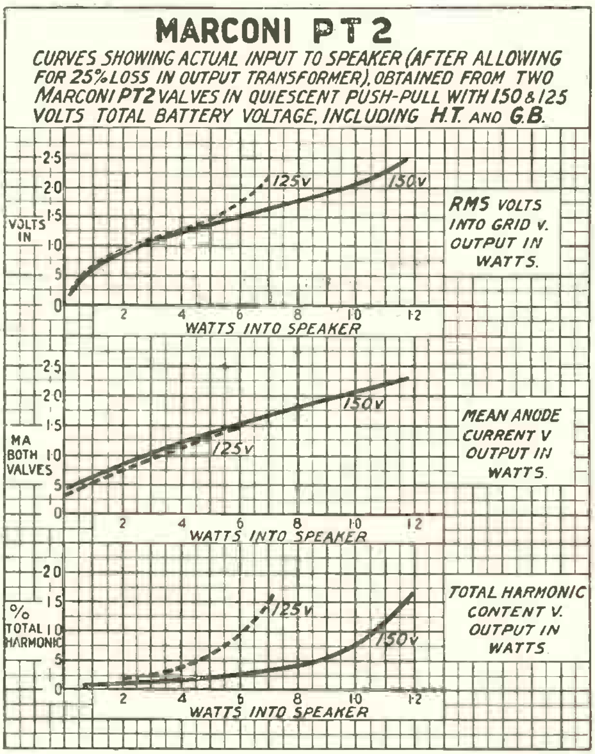


Fig. 3.—Outputs to be obtained with Marconi PT2 Q.P.P. Stage in Various Working Conditions.

Most Satisfactory Method of Biassing

The most satisfactory method of biassing is by means of a 25,000 ohm-wire-wound potentiometer placed across the grid bias battery. Not only does this enable a fine adjustment of bias to be carried out, but also provides semi-automatic grid bias. This means that the grid bias volts will drop as well as the H.T. voltage as the battery ages, so that frequent re-adjustment of the bias will not be necessary. It will be seen from Fig. 2 that a three-point switch has to be used with this scheme.

Biassing Directly from the Tappings

Those who wish to avoid the additional complication of potentiometer bias can, of course, sacrifice some of the H.T. current economy and bias directly from the tappings. In that case the end of the

150,000-ohm resistance shown in Fig. 2 connected to the potentiometer slider should go straight to G.B.—, and, of course, the three-point switch need not be used.

How to Use the Potentiometer to Obtain Correct Bias

To bias without a meter, but using the potentiometer, proceed as follows :—

Make sure that the grid bias voltage available is at least double the correct bias for the type of output valve when used singly. Wire up as the circuit in Fig. 2, place all the valves in their holders, except one of the output valves. Turn the potentiometer so that the full negative bias is applied. That is to say, the potentiometer slider is next to the terminal going to G.B.— maximum ; switch on, rotate the potentiometer back slowly until the signal is heard, but the reproduction is badly distorted. Switch off, place the second valve in the holder, switch on. Rotate the potentiometer very slowly back until the distortion *just* disappears. On no account should the potentiometer be rotated beyond this point.

Checking the G.B. Setting

If at any time it is desired to check the G.B. setting, one of the output valves should be taken out. The reproduction should then be badly cracked ; if that is not the case, the set is not being worked at the most economical G.B. setting, and the grid bias should be increased until, while there is no distortion when both valves are used, serious distortion is heard with one valve only in position.

Biassing without a Potentiometer

To bias without a potentiometer, start by giving maximum negative bias, which, as before, must be about double that required for the normal operation of the output valves used singly. Switch the set off, and try the next tapping. On no account should the bias plug be moved while the set is switched on. Find a tapping with which the reproduction is good, while that obtained by placing the plug in the adjacent more negative tapping is definitely cracked. It must be realised that as the battery ages, periodical readjustment of the G.B. will be required, and that care must be taken to work always with maximum bias consistent with clear reproduction.

Why the Two Fixed Resistances are Essential

The two fixed resistances in Fig. 1 are absolutely essential to maintain stability. Some pentode valve manufacturers recommend shunting the primary of the input transformer with a 50,000 or 75,000-ohm resistance. This can be connected across terminals PL and plus H.T. of the tone-control input transformer without affecting its performance.

The usual compensation of condenser ·01 mfd. and a 20,000-ohm in series across the output need not be used with the above circuit, since tone control is available. Should it happen, however, that the set becomes unstable in the all-top potentiometer position, the compensator should be connected across terminals 1 and 2 of the choke.

Valve Holders

The valve holders shown are of the five-pin variety. If triodes are used, four-pin holders will of course do, since there is no screen connection. The same applies to pentodes fitted with side terminals.

Loud Speakers for Use with Q.P.P. Output

Any loud speaker can be used with Q.P.P. output. Moving-coil instruments are, of course, not essential, and good results will be obtained with high-resistance speakers such as the inductor. In any case, the matching process is very simple. A moving-coil speaker is usually fitted with a tapped output transformer. The greatest step-down ratio is chosen on the output transformer, which is then connected to that pair of choke terminals which gives the best result, *i.e.*, either to 1 and 2 or 3 and 4 or 5 and 6, while high-resistance speakers are connected directly to the choke.

Pick-up Connections

Provisions for pick-up connection for gramophone reproduction are incorporated in most receivers. In any case, the connection is essentially simple, one terminal of the pick-up going directly to the grid of the detector, the other to grid bias minus 1·5. The same connection holds, of course, for a circuit used for gramophone amplification only. A medium impedance valve (15,000 ohms) should be used in the first stage. It is desirable to use metal-braided leads for pick-up connection, the metal braiding going to L.T. –.

Components Required for Q.P.P. Output Stage

The principal contructional points have now been given. The following components are necessary for the construction of the Q.P.P. output stage. It should be noted that the potentiometer used for grid bias must be wire-wound and must be of the stated value in all cases, except that in which a second potentiometer across the grid bias is used for a variable-mu valve. Both potentiometers should then be 50,000 ohms.

INPUT TRANSFORMER.—Multitone type Puco 1/8, with Multitone graded 4-megohm potentiometer.

OUTPUT CHOKE.—Multitone Puchoke.

25,000-OHM WIRE-WOUND POTENTIOMETER (*Lewcos*).

THREE-POINT SWITCH (*Bulgin*).

RESISTANCES.—50,000 and 150,000 (*Lewcos*).

NOTE ON TONE CONTROL PROVIDED IN THE CIRCUIT

The tone-control potentiometer should be set in the middle position when preliminary adjustments are being made. When, however, the set or amplifier is ready correctly wired and biassed, full use can be made of this control to get the best tonal balance in different working conditions. For gramophone reproduction, for instance, the most pleasant results will be obtained with the potentiometer turned to the bass end. Speech sounds most intelligible when high notes predominate, while heterodyne whistles and needle-scratch can be suppressed with some loss of high frequencies in the reproduction.

It will be found when listening to orchestral items, for instance, that the volume appears to be maximum in the central setting of the potentiometer. This effect is inevitable in all tone-control circuits. When listening to frequency broadcasts of the B.B.C. it will be found, however, that turning the potentiometer to the all-bass position while the low note is given out, will considerably increase the volume above that obtained with the potentiometer set centrally, while rotation in the opposite direction will have the same effect on high notes round about 5,000 cycles.

DIALS FOR TUNING CONDENSERS

POINTS to bear in mind when choosing a tuning dial are general appearance and utility, neatness and uniformity of style. On the practical side, reject any slow motion dial that is so made that the calibrated dial can be forced—or allowed to slip out of register with the moving vanes. The "J.B." drum dial and the "J.B." illuminated dials are reliable and practical; the "Ormond" illuminated logging drum dial No. R419 (see Fig. 1) has provision on each side of the 180 degree scale for logging selected stations on medium or long waves. The Burndept "Ethovernier" has an 18 to 1 reduction and is very effective—a removable scale is supplied on which station names can be marked.

Fig. 1.—LOGGING DIAL.

Dial Window Knobs

This is a small knob supplied by "Wearite," having a window or opening in it—giving access to a plain—or engraved—dial.

AUTOMATIC VOLUME CONTROL

By FRANK PRESTON

A PREVIOUS article on page 965 dealt with some of the applications of the variable-mu valve, and it was pointed out that one of its most important advantages was that it could be employed to provide an automatic control of volume. It is very probable that in future receivers this application will be made use of rather extensively, so it will be interesting to consider the basic principles and some of the methods of obtaining A.V.C.

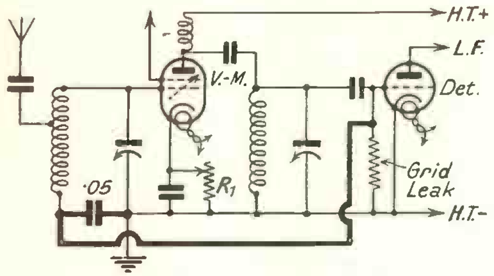


Fig. 1.—SHOWING THE PRINCIPLE OF AUTOMATIC VOLUME CONTROL.

The voltage drop across the detector grid leak is applied to the V.-M. valve as grid bias.

The Simplest A.V.C. Arrangement

The simplest possible arrangement of an automatic volume control circuit is shown in Fig. 1; the normal circuit of the V.-M. and detector valves is indicated by faint lines, whilst the A.V.C. modification is shown by means of heavier lines. The fundamental circuit is not necessarily that which would be used in practice, but has been reduced to its simplest terms for purposes of clarity. For example, a single-circuit aerial tuner replaces what would in practice probably be a band-pass filter, whilst wavechange switching and other "et ceteras" have been omitted.

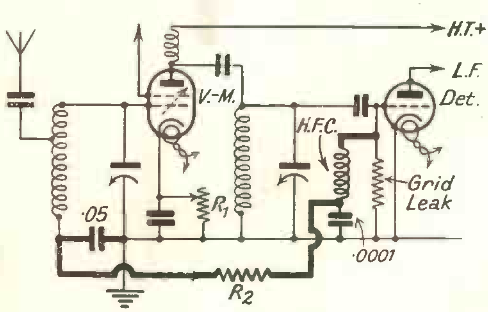


Fig. 2.—A PRACTICAL ARRANGEMENT OF FIG. 1.

A filter circuit is inserted in the grid-bias supply lead.

Constant Volume

We saw before that the object of A.V.C. is to reduce the amplification, or "gain," of the H.F. amplifying valve or valves when a strong signal is tuned in, and to increase it on weak signals. The net result is that volume remains constant regardless of the intensity of the signal being dealt with, and, moreover, the difficulties arising from the phenomenon known as fading are at once swept away. At least, this is the theoretical result, but in practice we rarely attain quite such an ideal state of affairs. Nevertheless, by careful design it is certainly possible to keep the volume within fairly narrow limits, those limits being determined by the methods employed and the general design of the receiver.

Using the Voltage Drop Across the Grid Leak

There are two general systems of A.V.C.; one in which the normal detector valve also serves the purpose of providing the control, and another where a separate control valve is used. The former is more readily understandable, so we will start by first considering this. Now we know that a certain amount of current flows through the grid leak of a normal leaky grid detector and also that the value of the current is dependent upon the strength of the signal. We also know that the voltage drop across a resistance (the grid leak in this case) varies in proportion to the current passing through it.* If, therefore, we can use the voltage drop across the grid leak to bias our V.-M. valve we shall obtain a grid-bias voltage which will vary with the signal voltage applied to the detector, and thus the essence of an automatic volume control circuit.

Referring to Fig. 1, we see that a connection is taken from the "grid" end of the detector grid leak to the grid of the V.-M. valve, through the tuning coil. To avoid short-circuiting the grid leak the direct connection between the lower end of the aerial tuning coil and earth has been replaced by a ·05-mfd. fixed condenser, the purpose of which is to allow free circulation of high-frequency currents whilst acting as a barrier to direct current.

Minimum Bias

The variable resistance connected in the cathode lead of the first valve (marked R. 1) is that normally employed for providing automatic grid bias, but its purpose now is merely to supply the minimum bias voltage necessary to prevent the flow of grid current. Incidentally, however, it can still be used as a manual volume control to regulate the maximum volume required.

H.F. "Stopper" Circuit

The arrangement we have considered, although convenient as demonstrating a principle, would be useless in practice. The reason is that, in addition to the normal D.C. current, there is also a certain amount of H.F. flowing through the grid leak and which would be passed back to the first valve, so causing instability. This can be prevented by the use of an H.F. stopper and filter circuit consisting of an ordinary H.F. choke, ·0001-mfd. fixed condenser and decoupling resistance (R. 2) connected as shown in Fig. 2. The value of R. 2 is not at all critical, but should be two or three times that of the grid leak.

In Fig. 2 we have a workable arrangement, and we have considered all the components excepting the bias resistance R. 1. Actually nearly any value will serve for this, since it is a variable component, but we can assign to it an approximate maximum resistance in the region of 10,000 ohms.

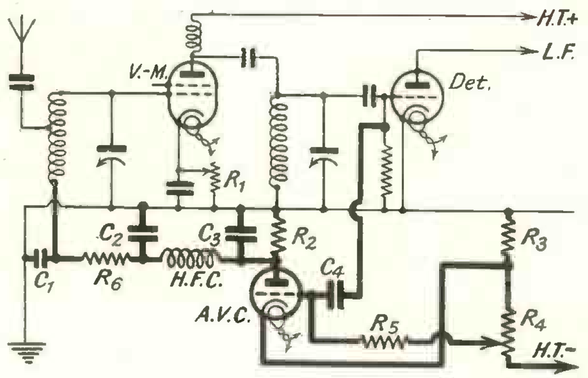


Fig. 3.—HOW A SEPARATE VALVE IS EMPLOYED FOR AUTOMATIC VOLUME CONTROL.

Limited Control

Unfortunately there is a rather serious practical objection to the simple circuit arrangement just considered, because the voltage variation across the grid leak is extremely small and thus the degree of control which it can provide is very limited. In consequence, the system cannot successfully be applied to a receiver having only a single V.-M. valve, although its effectiveness increases rapidly with the number of V.-M. valves in use.

For instance, the control is proportional to the square of the bias voltage when two valves are employed, or to the cube in the case of three valves. In actual fact it has been found possible to maintain a reasonably constant volume level by this system with a "three-V.-M." receiver, but with any other type of set, excepting perhaps a sensitive superheterodyne an appreciable variation in volume occurs on signals of different intensities.

* This latter point is made quite clear by considering Ohm's Law, which states that the Voltage Drop is equal to the product of the Current and the Resistance. Since the Resistance remains constant, it is obvious that the other two expressions must be proportional.

A Separate A.V.C. Valve

A more satisfactory way of applying A.V.C. to any type of V.-M. receiver is that in Fig. 3, where a separate "control" valve is employed.

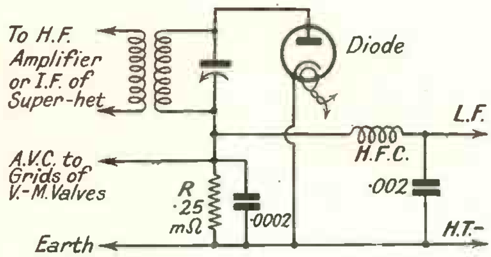


Fig. 4.—Automatic Volume Control by means of a Diode Detector.

The object of the latter valve is, in effect, to amplify the voltage variations occurring across the grid leak before they are applied to the V.-M. valve as grid bias. This scheme is thus applicable to a receiver having only a single V.-M. valve.

The control valve is arranged as an anode-bend detector, and its grid is connected to that of the normal detector valve so that it receives exactly the same signal voltages. Now the anode current of an anode-bend rectifier is proportional to the grid voltage, with which it rises and falls in sympathy. This current is therefore passed through a resistance (marked R. 2) and the varying voltage drop across the latter is applied to the V.-M. valve as grid bias.

If we examine the circuit of Fig. 3 in more detail we find that the anode of the control valve is connected to the common cathode lead through a fixed resistance R. 2, whilst its cathode is maintained at a lower potential by means of resistance R. 3 inserted in the H.T. negative lead to the receiver proper. The grid of the valve is given a still lower potential due to its being connected to the potentiometer R. 4; the grid is also connected to the grid of the detector valve through the fixed condenser C. 4.

Method of Operation of Control Valve

Let us see how the control valve operates. The potentiometer R. 4 is first adjusted until the anode current is zero, when no signals are being received; under such conditions there is no current through R. 2 and consequently no voltage drop. Hence the bias voltage applied to the V.-M. valve through the smoothing circuit comprising C. 1, R. 7, C. 2, H.F.C. and C. 3 is zero. But immediately a signal is tuned in anode current flows to the control valve through R. 2 and a voltage drop occurs across that resistance; this is therefore applied to the V.-M. valve as negative bias. The more powerful the signal the greater the anode current becomes, and hence the higher is the controlling bias and the lower the amplification afforded by the V.-M. valve.

Practical Details

What about the practical details of the circuit? The control valve may be any medium-impedance A.C. triode, such as Mullard 164 V, Cossor 41 MLF or Marconi M.H.L. 4. A suitable anode voltage for any of these valves is about 60, and this must be developed across R. 3, whose resistance can be calculated by dividing the total current consumption of the set into 60.

An Example

For example, suppose the anode current consumption were 30 milliamps (30/1,000 amp.), the resistance should be 60/1 × 1,000/30, or 2,000 ohms. Potentiometer R. 4 must develop a maximum voltage drop of about 8 volts, so its value is found by dividing 8 by 30/1,000, and this works out at approximately 250 ohms. A potentiometer of this or any higher value up to 500 ohms would thus be perfectly suitable. Resistance R. 5 is a grid leak of 1 megohm

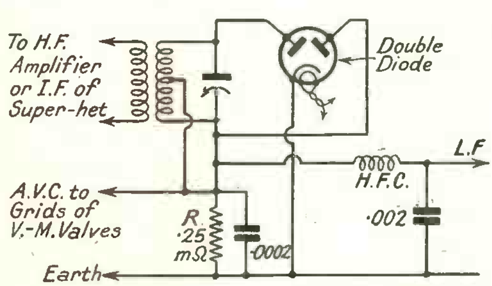


Fig. 5.—In this Circuit a Double-diode is used for Full-wave Rectification and Automatic Volume Control.

or so, and the grid condenser C. 4 should have a capacity of ·001 mfd. The anode resistance R. 2 should have a value of 15,000 to 20,000 ohms, whilst the decoupling resistance R. 7 may be anything from ·1 to ·5 megohm; H.F.C. is an ordinary high-frequency choke, whilst condensers C. 1, C. 2 and C. 3 are each of ·05 mfd.

It can be seen that the voltage obtained across R. 3 and R. 4 is actually taken from the main high-tension supply and thus the voltage of the latter must be from 60 to 70 volts higher than is required by the receiver in the normal way. Since the cathode of the control valve is at a potential of some 60 volts lower than those of the receiving valves, its heater should be fed from a separate winding on the mains transformer.

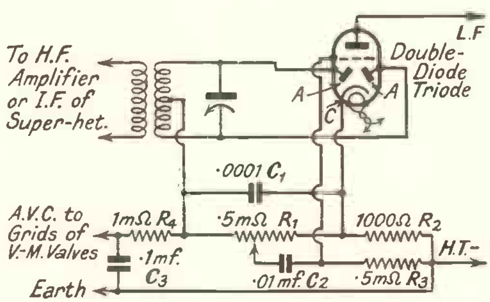


Fig. 6.—A Double-diode Triode is here employed as a Combined Detector, Automatic Volume Control and L.F. Amplifier.

A Disadvantage of Separate Control Valve

The fact that an increased H.T. voltage is necessary makes the latter system of A.V.C. somewhat inconvenient and rules out the possibility of its easy application to an existing set. In addition, the need for an extra valve adds to the expense of the complete receiver and may thus be counted as a further disadvantage.

Other Systems

Numerous other systems have, therefore, been developed which make use of special valves designed to serve the dual function of detector and volume control. We cannot discuss all the various arrangements here, but it might be of interest to summarise the more important ones, and especially those which have already been incorporated in receivers at present on the British market. Incidentally, it should be mentioned that very rapid strides are being made at the present moment in this direction, and new schemes are being evolved so rapidly that there is some difficulty in keeping pace with them.

A Diode Detector-control Valve

The simplest A.V.C. system where an extra control valve is not required, and which has found practical application, is that making use of a diode detector. This type of detector has been used for some time in "quality" receivers of the more powerful type and possesses the advantage of being able to handle a large signal input without distortion. It is generally fed from an H.F. amplifier having two or more stages, or is used as second detector in superheterodynes. In either case the variations of input voltage are comparatively great and can therefore be employed to supply an adequate biasing potential for A.V.C. purposes.

The circuit of a diode used as a combined detector and control valve is shown in Fig. 4; the potentials developed across the grid-leak R are applied to the preceding V.-M. valves through the usual filter circuit.

Double-diode

Another similar arrangement where a double-diode is used as a full-wave rectifier and control valve is shown in Fig. 5. The functioning is almost identical with that of the circuit of Fig. 4, but rectification is somewhat more efficient; grid bias is obtained exactly as before across the grid-leak R. One slight difficulty which arises in connection with the construction of a receiver using a double-diode is that the grid coil must be tapped at its exact "electrical" centre; this is often quite different to the "mechanical" centre and must thus be determined experimentally.

The Double-diode Triode

Although the use of a diode in the manner referred to "saves" a valve, the benefit is not so great as might at first appear, because a diode is appreciably less sensitive than a leaky-grid or power-grid detector. In consequence, it might entail the addition of a further L.F. amplifier to bring the output volume up to the same level as would be obtained when using a detector valve of the somewhat more conventional type. To overcome this difficulty a valve has recently been introduced which combines the function of a double-diode detector-control valve and of a triode amplifier. It is called a double-diode triode and is connected in circuit as shown in Fig. 6.

This circuit might appear somewhat complicated, so a brief explanation seems desirable. The two auxiliary anodes (indicated A-A) provide full-wave rectification in conjunction with the cathode C, and the rectified voltage is developed across the grid-leak R. 1. The D.C. component is filtered through the circuit comprising R. 4 and C. 3 and is fed directly to the V.-M. grids as grid bias. The audio frequencies, however, are passed through the condenser C. 2 to the grid of the triode and are thus amplified before being passed on to the ordinary L.F. amplifier. Anode current flowing through the resistance R. 2 provides the necessary automatic grid bias for the triode. Resistance R. 3 is merely for decoupling purposes, whilst R. 1 serves as a manual volume control on the triode portion of the valve.

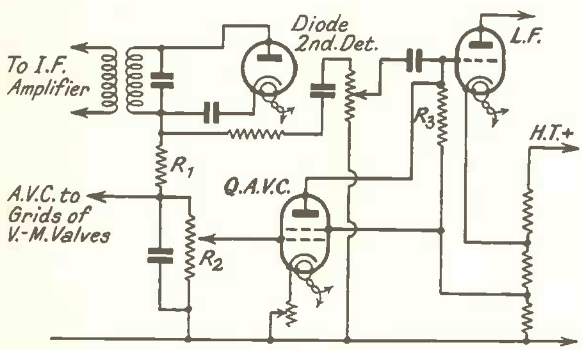


Fig. 7.—A System of Quiet Automatic Volume Control employed in a Well-known American Superheterodyne Receiver.

In the absence of signals a high anode current flows to the quiet automatic volume control valve through R. 3 and causes excessive bias to be applied to the L.F. valve.

"Quiet" Automatic Volume Control

The greatest objection to A.V.C. is that although it provides a constant signal level on all programmes it gives undesirable prominence to various forms of "mush" and parasitic interference which are encountered when tuning from one station to another. This is obviously because maximum amplification is given to the interference which is, in the ordinary way, so faint as to be barely noticeable. The effect is very trying when "searching" with a sensitive receiver, because whilst rotating the tuning dial one has the experience of going from one programme to "noise," from a second programme to more noise, and so on.

In the same way, when listening to a station which is subject to fading, the signal volume certainly remains constant, but one finds the reverse effect of increasing and decreasing strength of "mush." This disadvantage has been recognised, and various methods have been devised for combating it. Thus, circuits incorporating "noise suppressor" or "quiet automatic volume control" (Q.A.V.C.) devices are being widely experimented with and have, in fact, reached the "commercial" stage in America.

Typical Examples

One method of obtaining Q.A.V.C. is so to arrange the control valve that it renders the V.-M. stages inoperative on signals of less than some pre-determined intensity. Another is to design the control circuit in such a way that it acts not only on the H.F. portion of the circuit, but also on the L.F. amplifier; when maximum bias is applied to the H.F. stages the L.F. works at full efficiency, but when the H.F. bias falls to zero or a very low figure, the L.F. amplifier becomes inoperative, due to its being biassed so heavily that it will not respond to signals applied to it.

The former system is somewhat involved and requires for its efficient working a pair of double-diode triode valves, so we will not go into it here. The latter method, however, is a good deal simpler and may be operated through a single A.V.C. valve; as a matter of fact, it is not yet employed in any receiver on the British market, but Fig. 7 shows the principle features of a control of this type which is embodied in one well-known make of superheterodyne of American origin.

A diode is used as second detector, and this provides a variable grid bias to the V.-M. valves by the voltage drop across R. 1. A variable-mu valve serves as a quiet automatic volume control; when signals are tuned in it is biassed by R. 1 (and by adjusting R. 2) to a point at which its anode current is zero. But when the set is not tuned to a station the bias voltage to the Q.A.V.C. valve is reduced, and the latter therefore passes anode current. As the current is drawn through resistance R. 3 connected in the grid circuit of the L.F. valve the voltage drop across that resistance is applied as additional grid bias to the L.F. amplifier, which is thereby prevented from functioning. It can thus be seen that all signals below a pre-determined intensity are prevented from reaching the loud speaker even though they are amplified in the usual way by the H.F. stages.

Practical details of the circuit of Fig. 7 cannot be given, since the values of components will vary tremendously with the types of valves and the H.T. voltages employed.

PRACTICAL WIRING HINTS

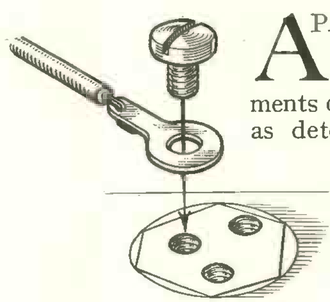


Fig. 1.—A Tag Soldered to Glazite Wire.

APART from necessary arrangements of the wiring as determined by the nature of the set, the wire used should be short and comparatively thick tinned copper, say, 16 to 20 gauge.

When much soldering has to be done use bare wire and cover the exposed parts with insulating sleeving.

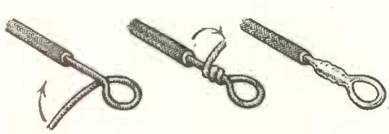


Fig. 2.—How to form Eyes on a Flexible Wire.

Bare the insulation, bend the eye, and twist the end around the shank and solder.

For all-round practibility and neatness use Lewcos, "Glazite"; whenever a flexible is wanted use "Lewcoflex," it is neat in appearance, is available in six colours.

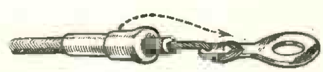


Fig. 3.—A Tag End for a Flexible Wire.

Solder the flexible to the tag, then push the rubber sleeve over the soldered shank.

"Quick-wyre" is an 18-gauge tinned copper wire covered with cotton braiding, it saves time when wiring up, the wire is merely cut to length and the braiding pushed back. "Soldawyre" is a stranded flexible wire with one strand of solder wire; with it, soldered eyes and neat endings are quickly attained.

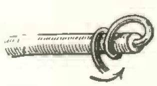


Fig. 4.—Belling - Lee Side Fixing System.

Connecting Wires to Fittings

"Glazite" can be bent into an eye and slipped over the terminal or can be inserted in the small hole in a soldering tag—as shown in Fig. 1. Flexible wire ends should be twisted into an eye as in Fig. 2 and soldered, or can be soldered to a tag—as in Fig. 3—and the end covered with sleeving.

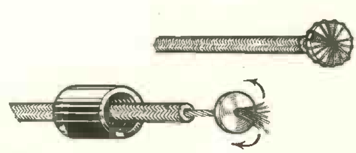


Fig. 5.—Belling-Lee End Fixing.

Slide the fitting cap up the flexible, put wire through hole in washer and bend the strands around it.

A FOUR-VALVE PORTABLE

By EDWARD W. HOBBS

GANGED dual range tuning is the outstanding feature of this sensitive and powerful four-valve portable receiver. The theoretical circuit is given in Fig. 1.

Features of the Circuit

The frame aerial consists of two distinct windings, the longer of which can be shorted when reception is desired on the medium wave band.

To ensure accurate matching, small adjustable inductances are included at the ends of each winding—their full purpose will be explained later.

The high-frequency signals are fed to the grid of a screen-grid valve and amplified as usual, then handed on to the tuned grid circuit of the detector valve, the latter being resistance-coupled to the first L.F. valve, and that in turn coupled by a L.F. transformer to the power output valve.

An interesting feature is the use of resistances for control of H.T. feed voltages, while the provision of a volume control acting on the grid of the S.G. valve is of great value when handling the set.

MATERIALS REQUIRED

The following is a list of the essential components for the set :—

TUNING CONDENSER.—1 "J.B." "Nugang" Unitune dual ·0005 mfd. ganged condenser with slow-motion dial (" *Jackson Bros.*").

REACTION CONDENSER.—1 "J.B." "Differential" ·0003 mfd. (" *Jackson Bros.*").

COIL.—1 dual range H.F. and aerial coil No. 154 (" *Telsen* ").

H.F. CHOKES.—1 Midget type (" *Graham Farish* ") ; 1 "Wearite" H.F.P. (" *Wearite* ").

L.F. TRANSFORMER.—1 "RI" "Dux" (" *Radio Instruments Ltd.*").

VALVE HOLDERS.—4 4-pin (" *Lotus* ").

VOLUME CONTROL.—1 Q.5 30 ohms ganged with on-off switch (" *Wearite* ").

FIXED RESISTANCES.—1 50,000 ohms ; 1 25,000 ohms ; 2 2-megohm (" *Erie* ") ; 1 25,000 ohms Spaghetti (" *Lewcos* ").

FIXED CONDENSERS.—1 2-mfd. ; 3 1-mfd. ; 1 ·05-mfd. ; 1 ·0001-mfd. ; 1 ·0003-mfd. ; 1 ·005-mfd. ; 1 ·01-mfd. (" *T.C.C.*").

WAVE-CHANGE SWITCH.—1 triple break, No. G.W.C. (" *Wearite* ").

VALVES.—1 No. S215 (" *Osram* ") ; 1 No. PM2DX, 1 No. PM2 (" *Mullard* ") ; 1 No. L.2, metallised (" *Mazda* ").

LOUD SPEAKER.—P.M. moving-coil "Challenger" (" *R. & A. Ltd.*").

BATTERIES.—1 H1040, 1 H1005 "Drydex" (" *Exide* ") ; 1 Gel-Cel J.W.F.7 (" *Exide* ").

TERMINALS.—2 twin socket strips ; 4 "N" type terminals ; 5 wander plugs ; 2 battery tags (" *Belling Lee* ").

WIRING.—1 coil "Glazite" ; 3 yards "Lewcoflex" ; 1 oz. each No. 26 D.S.C. and No. 32 D.S.C. (" *Lewcos* ").

FUSE.—Scrufuse and holder, 150 milliamperes (" *Belling Lee* ").

METAL FOIL.—1 piece 14 by 6 inches.

MATERIAL FOR CASE.—1 sheet 4 mm. plywood, 42 by 36 inches ; 1 10-inch circular fret ; 15 feet $\frac{5}{8}$ by $\frac{3}{8}$ inch deal ; 6 feet, 6 inch by $\frac{1}{4}$ inch deal ; 1 piece 14 by 11 by $\frac{3}{8}$ inch plywood.

BASEBOARD.—Plywood $\frac{3}{8}$ by 14 by 6 inches.

What to do First

The first thing to do is to make up the frame for the aerial, as shown in Fig. 2, where all dimensions are given. It consists of four flat strips of wood glued and nailed together at the corners.

Next glue and pin narrow strips of wood around the outside edges, so that a

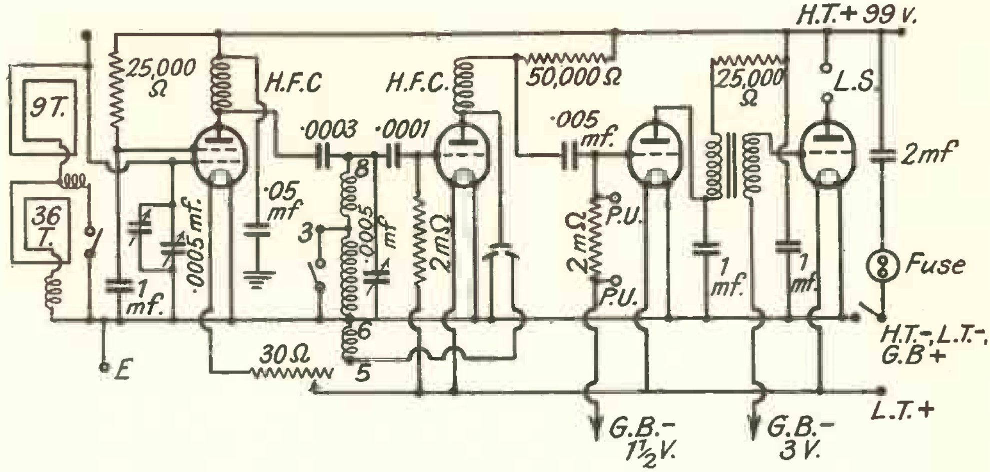


Fig. 1.—THE CIRCUIT.

Special balancing inductances are incorporated in the frame winding to enable satisfactory ganging on both wave ranges.

trough or hollow is left between them, as in Fig. 3.

Follow this by screwing the two cross bearers in place, as in Fig. 4, and fix a batten across the back for the baseboard of the set to rest upon. Note that it is cut away, as shown in Fig. 4, to provide clearance for components.

The Baffle Board

Cut the baffle board to shape, as shown in Fig. 5, then glue and screw it inside the frame, but flush with the front, as shown in Fig. 6, and take care to see that all is square and true at this stage.

Fit a batten across the bottom to hold the H.T. battery; see that it fits closely against the baffle board and is flush with the back of the frame.

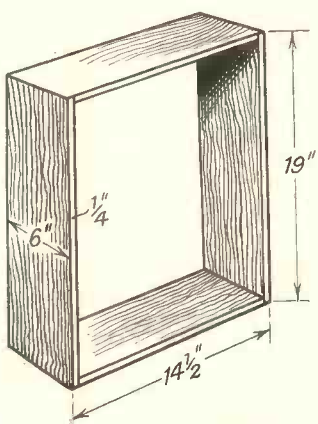


Fig. 2.—FRAME FOR AERIAL.

This forms the inner lining of the complete case; it must be perfectly square and true.

Lining the Baffle Box

Line the whole of the loud speaker compartment with thick felt or with cotton-wool covered with linen and fixed with gimp pins.

Next cut eight pieces of strip wood to length for the spacer strips, so that they fit snugly between the rims of the trough on the frame, then mark them for the winding spacings.

To do this, obtain a long "stove screw," ¼ inch diameter, from any ironmonger.

Cut off the head, then use the screw like a roller to indent evenly spaced lines across the strips. The screw has sixteen

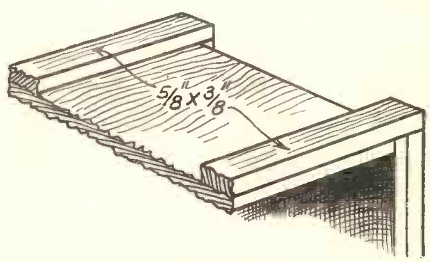


Fig. 3.—EDGING STRIPS.

Strips of wood are next glued and nailed around the outer edges to form a trough.

threads per inch, consequently the lines formed on the strips will be $\frac{1}{16}$ inch apart.

Grooving the Spacer Strips

The most effective way to indent the grooves is to lay the strip flat on the table, put the screw on it, placing it lengthways, as shown in Fig. 7, and roll it from side to side with the aid of a flat-iron or some similar implement. This treatment quickly indents the wood and provides the grooves for spacing the aerial windings.

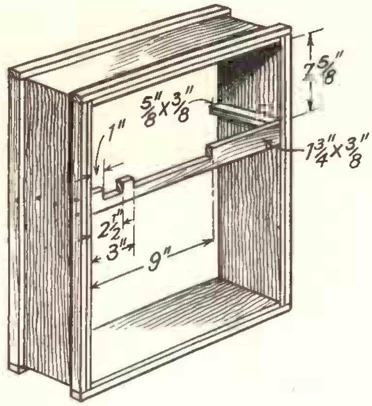


Fig. 4.—Bearers for Baseboard.

Strips are screwed inside the frame and a notched crossbar across the back as here shown.

Glue a strip to each corner, as in Fig. 8, allowing it to overhang $\frac{1}{8}$ inch as shown; glue another spacer midway between each corner strip. The purpose of these strips is to hold the wires firmly and keep them off the wooden frame.

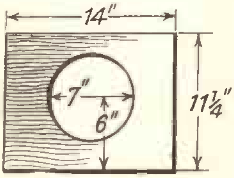


Fig. 5.—Baffle Board.

This should be shaped from $\frac{3}{8}$ inch thick plywood and must fit snugly into front of frame.

Winding the Frame

Particulars of the winding and their spacing are given in Fig. 9. Put the medium-wave winding on first, and fasten the wire to terminals placed as in Fig. 9, then make the requisite number of turns, spacing them evenly and taking care to keep them tight. Any slackness will allow the wires to vibrate, and if they do this they will cause parasitic noises in the receiver.

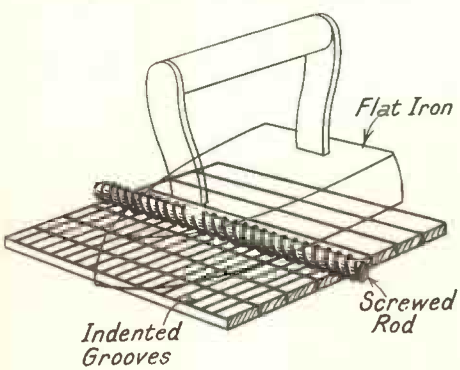


Fig. 7.—Indenting the Spacer Strips.

Place a headless screw on the strips and roll it over them as here shown, using a heavy hammer or a flat iron.

Finish off the medium-wave winding by connecting it to a "tap" terminal.

Begin the long-wave winding at this terminal and solder the end of medium-wave winding and the start of long-wave winding to it.

Complete the long-wave winding with equal care and finish off as before; thus there will be four terminals, with wires attached to three of them, as shown in detail in Fig. 10. The internal connections are made later on.

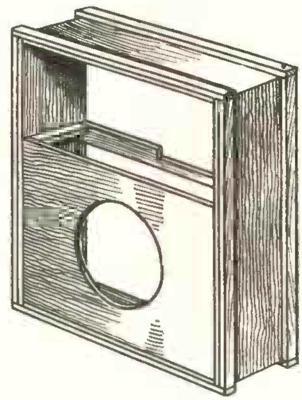


Fig. 6.—Baffle Board Fitted to Frame.

The addition of the baffle board stiffens the frame and holds everything square.

Mounting the Components

Next prepare the wooden baseboard, which measures 14 inches long, 6 inches wide, and should be $\frac{3}{8}$ inch thick. Cover the top with metal foil, then screw the various components into place, as shown in Fig. 11, taking care to see that fittings such as valve holders do not "short." If in doubt put a disc of thin "bakelite" or card under them before screwing them down.

The next step is

the wiring, which should be carried out with "Glazite" in the usual way; it is quite a straightforward job, and the positions of the wires are shown clearly in Figs. 12 to 14.

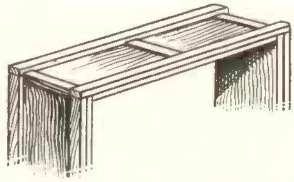


Fig. 8.—Spacer Strips in Place.

Spacers are glued to the corners of the frame also midway between them.

Loading Inductances

Next make the two loading inductances, as shown in Fig. 15, which gives details of the turns; both are wound with No. 26 D.S.C. wire in the same direction as the frame winding. Mount them on small ebonite or wood blocks under the top of the frame, and connect them to the frame aerial windings, as shown in Fig. 15, and see that the terminals cannot twist in the woodwork.

Prepare a temporary panel, as shown in Fig. 11, and mount the components on it, fasten it to the baseboard, then connect up these components as shown in Figs. 12 to 14. Afterwards use this temporary panel as a template for drilling the case front.

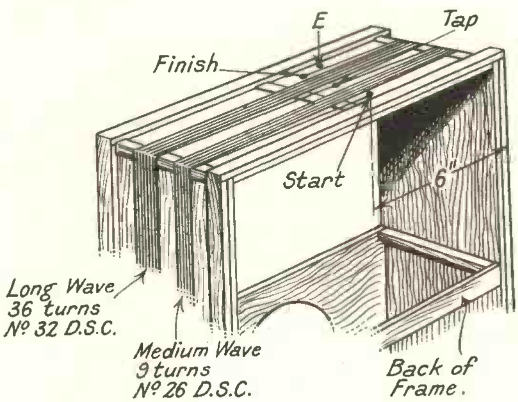


Fig. 9.—Winding the Frame.

Here is given the necessary data for winding the frame aerial. All turns are in the same direction. Terminals are fitted with the treads inside the case and shanks outside, the wires being soldered thereto.

Fixing the Loud Speaker

Screw the loud speaker in place in the lower compartment, taking care that it beds down firmly on the felt and makes an air-tight joint.

Put the H.T. battery and L.T. battery in place and connect them to the terminals on the set and to the switch, as shown in the drawings.

Check over the circuit and wiring, then put the valves in place and switch on the set.

Preliminary Tests

The frame aerial on this set is very markedly directional, hence it must be placed so that it points in the direction of the station to be received.

Now carefully tune in any station on the medium wave band, preferably a strong station at about the middle of the dial. Adjust the reaction very carefully and try the effect of the trimming condenser, which is controlled by the small central knob on the ganged tuning condenser.

Balancing the Aerial

Now pick out a powerful station near the top of the dial, say Prague, set the frame so that it points in the correct direction, then carefully tune it in, but do *not* move the trimming condenser. If the station comes in fairly strongly, all is well; then bring it up to full strength by careful adjustment of the trimmer.

Repeat the test with a station at the low end of the dial—for example, Fecamp.

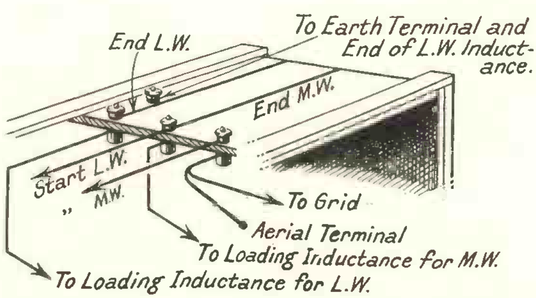


Fig. 10.—Arrangement of Frame Terminals.

This skeleton diagram shows the whereabouts of the terminals, and the connections made to them.

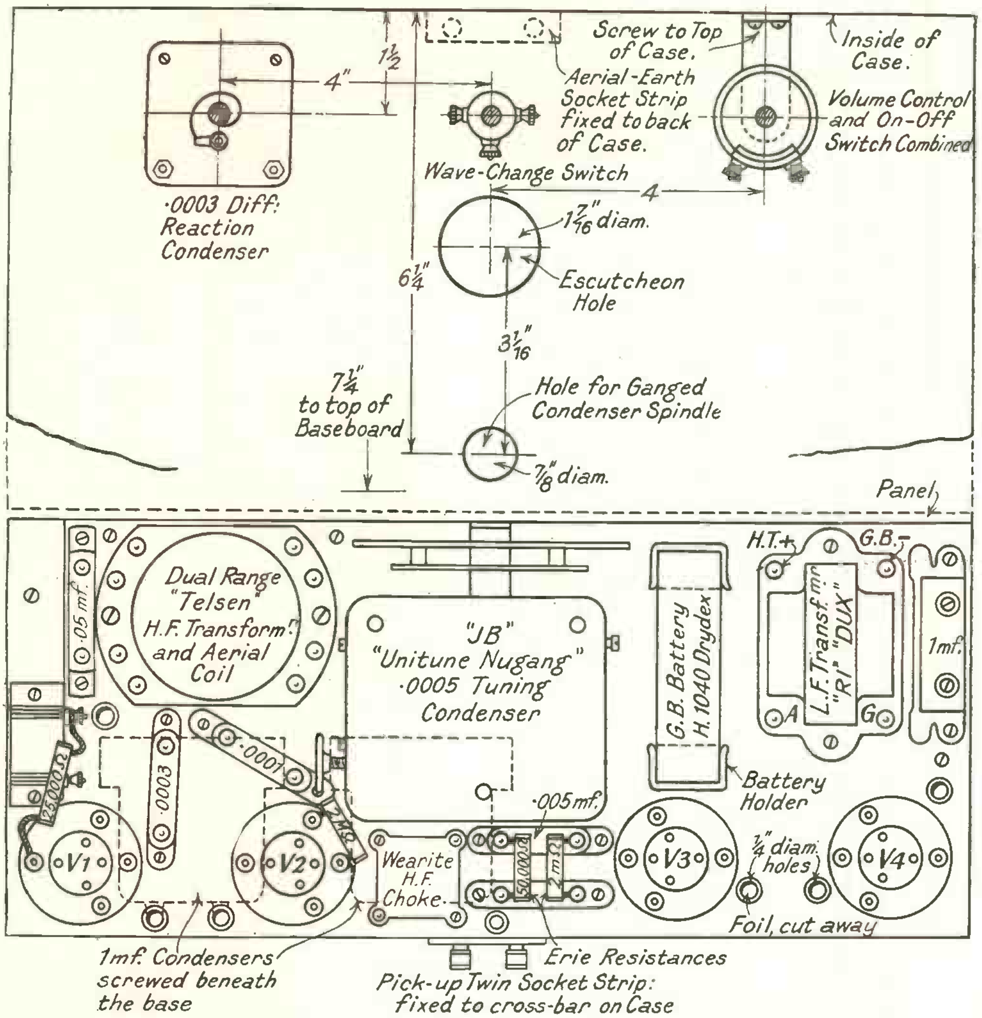


Fig. 11.—Arrangement of Components on Base and Panel.

This arrangement should be followed closely. Fittings on and under the baseboard are shown at the bottom, at the top are details of those on the panel. Note that the Wearite combined switch and volume control is fixed to top of case.

If the selected station comes in fairly strongly with the trimmer in its first position—the setting used for the midway station—all is well, and it only remains to tune in two or three stations on the long waves, which should be received without difficulty.

Adjusting the Local Inductances

In all probability if the set is made up exactly as described, no special adjustments will be needed; any slight errors can be dealt with by simply tuning with the main knob and bringing the station in at full strength with the trimmer knob. On the other hand, the ganging of a dual-range frame aerial is definitely a difficult matter, and the slightest variation in wire gauge, spacing, tightness of winding, and so on, may upset the ganging, in which case the set will not function properly.

The correct procedure then is to adjust the inductances and bring the frame windings into balance. This can be done

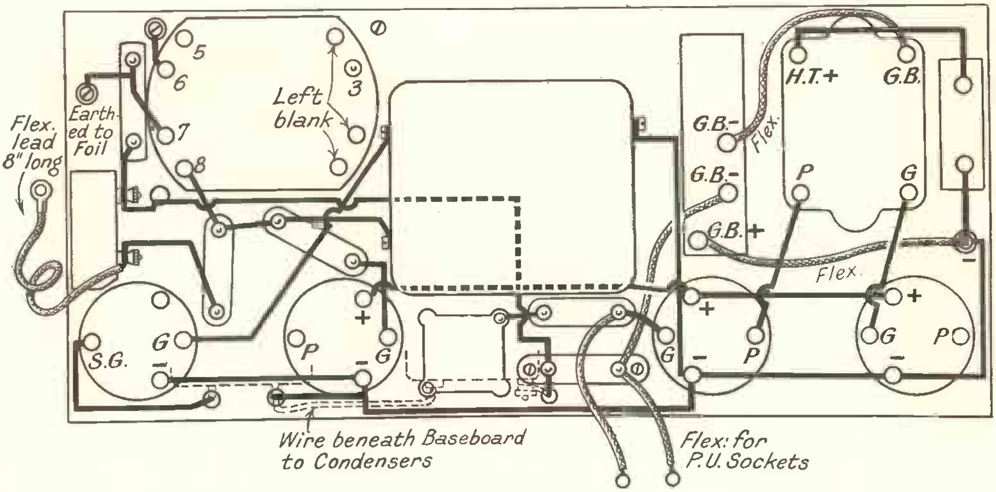


Fig. 12.—First Stage of Wiring.

Only the components involved are shown; most of the resistances will in fact be already in place.

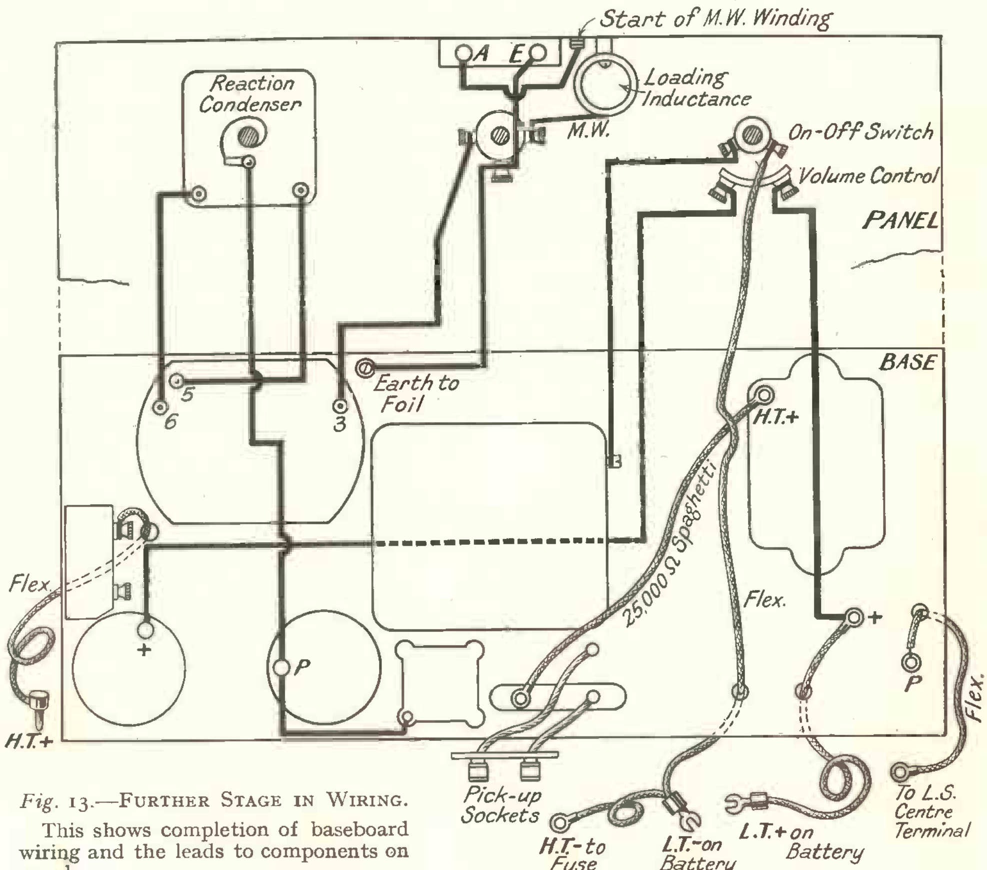


Fig. 13.—Further Stage in Wiring.

This shows completion of baseboard wiring and the leads to components on panel.

in various ways, but the following method is quite practical, and does not require any special instruments.

Correcting the Inductance

Before doing any experimental work it is necessary to realise that a frame aerial set tunes in the same way as any other, and, if the two circuits are to tune simultaneously, as they must do when "single-knob" or ganged tuning is employed, the product of L and C must be the same in each circuit for any given dial reading or wavelength.

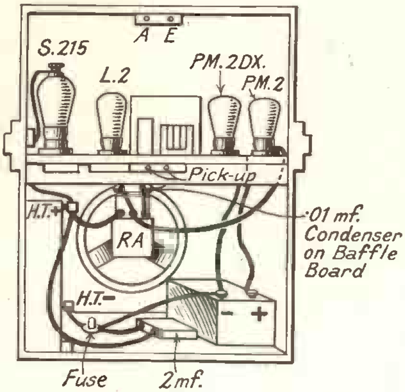


Fig. 14.—COMPLETION OF WIRING.
The loud speaker connections and those to decoupling condensers are here shown. This completes the wiring operations.

The dominating circuit in this set is the second or tuned grid circuit, because it tunes the amplified signals. Moreover, it is impracticable to vary the inductance of the grid coil—the ganged condensers cannot be altered; hence to balance the tuning or make it "gang" properly requires that the inductance of the frame shall be adjusted to bring it into step with that of the tuned grid circuit.

Hence when the set is *not* in balance, the inductance of the frame aerial winding must be adjusted either by increasing or diminishing its value.

Increasing the Value of Inductance

The difficulty is to know how much inductance has to be added to or subtracted from the frame aerial. Fortunately, this can be determined quite readily by simple practical methods. First tune in a fairly distant station on the medium waves at about the middle of the dial, then disconnect the wire from the grid of the first valve to the aerial tuning condenser, taking care not to disturb the setting of the condenser. There will be a loss of signal strength; this does not matter, but note carefully the dial reading, then carefully retune to bring the station to its maximum strength. If the dial has to be turned to the right—that is to increase the capacity of the grid circuit—it indicates that there is too much inductance in the aerial circuit. Conversely, if the dial has to be turned to the left, the inductance of the aerial circuit is too little.

Setting the Trimmer

The position of the trimmer, which is in the aerial circuit, will confirm the diagnosis. In the former case it will be found to be turned to the left, the minimum position; in the second case it will be to the right, the position of maximum capacity.

Repeat these experiments with stations near each end of the dial readings at, say, 20 degrees and 160 degrees. Suppose also that the error is plus 2 degrees at the centre, plus 4 at 160 degrees and minus 1 at 20 degrees, this would indicate that on the medium wavelengths the aerial inductance was too high at 160 and 90 degrees and scarcely enough at 20 degrees. These figures are extremes to emphasise the method of correction.

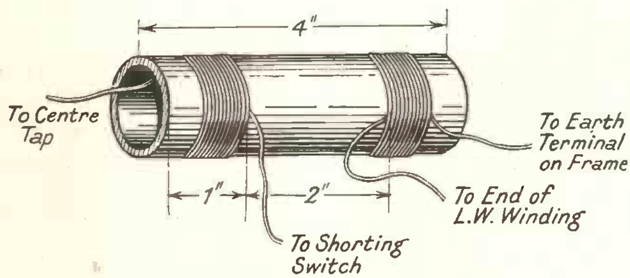


Fig. 15.—DETAILS OF LOADING INDUCTANCE.
The wire is No. 26 D.C.S. wound around a tubular former 1½ inches diameter and spaced as shown.

Adjusting the Aerial Circuit

To correct a fault such as the above, tune in the midway

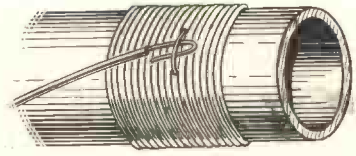


Fig. 16.—TEMPORARY TAPPING TO LOADING COIL.
For ganging purposes the grid wire is looped under a bared turn on the inductance.

station on the second circuit only with the aerial condenser disconnected. Set the trimmer to zero minimum value of condenser and reconnect the aerial condenser. Take care not to disturb the setting. Then disconnect the wire from the grid end of the medium-wave loading coil and try it at various positions on the coil, making a connection by scraping the insulation from a turn of the coil and looping the grid wire under it, as shown in Fig. 16. Now try the effect. The station should come in louder without adjustment of the tuning condensers. Continue reducing the amount of inductance in this way until the midway (90 degree setting or near) station is sharply tuned, or until the trimmer condenser has to be turned a trifle towards the right.

Now tune in the end stations as before, probably the 160 degree station will be a shade off tune, and the 20 degree station will be brought in by turning the trimmer nearly fully to the right. In that case reduce the inductance by one or two more turns, and take it as being correct for the present.

Ganging the Long-wave Winding

Now tune in several stations on the long-wave winding; they will probably come in without trouble and be sharply tunable with the aid of the trimmer, but if not, treat the long-wave winding in the same way by adjusting the inductance of the long-wave loading coil. In very bad cases it may be necessary to add or remove a complete turn or two of the frame aerial winding. When the set is properly ganged, the aerial trimmer condenser will tune most stations in or out after locating them with the main tuning condenser.

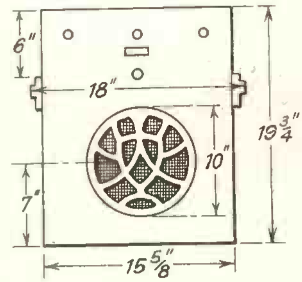


Fig. 17.—FRONT OF CASE.
The holes for components are spaced by the temporary panel. The circular fret is screwed in place from the back after the silk covering has been fixed.

Having thus far adjusted the set, tune in as many stations as possible and note the results, then carefully adjust the small star wheel on the grid-tuning condenser; this gives just the added touch that makes the tuning as perfect as possible.

Final Adjustments

In general, it is desirable to concentrate on the weak or distant stations that are most desired, the local and powerful stations invariably "spread" more, and are not so susceptible to minute inaccuracies of tuning as the distant stations.

If headphones are available they should be used in preference to the loud speaker while making these adjustments; with them two "peaks" can be heard distinctly when

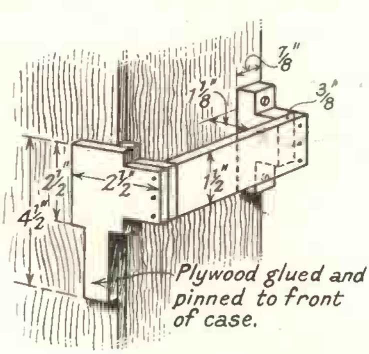


Fig. 18.—DETAIL OF HANDLE.

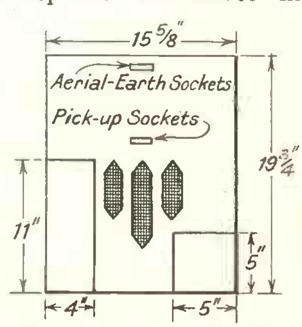


Fig. 19.—DETAIL OF BACK COVERING.
This is fitted similarly to the front; the fret is covered internally with gauze. Separate panels are provided for the battery compartments.

the ganging is not quite correct; the loud peak indicates that the grid circuit is sharply tuned, the second peak indicates when the aerial circuit is tuned. When headphones are used, the adjustments to the loading inductances can be made far more quickly and should be continued until the two "peaks" blend into one, thus indicating that ganging is correct, or as nearly so as is practicable without the resources of a test laboratory.

Completing the Set

Having now adjusted and ganged the set, and incidentally acquired a mastery of its tuning, it only remains to solder the wires permanently to the inductances and to complete the case. This is readily accomplished; all that is required is a sheet of veneered plywood, shaped as in Fig. 17, with a suitable "fret" for the loud speaker covered on the inside with gauze or silk.

Fitting the Panel

The panel is glued and pinned to the front edges of the frame and finishes flush all round. Holes must of course be drilled in the upper part for the spindles to pass through and for the dial escutcheon.

The Sides, Top and Bottom

The sides, top and bottom are then covered with strips of plywood fastened in place with countersunk screws, or with glue and cabinet pins, and two shaped blocks screwed to the sides, as shown in Fig. 18, to act as handles.

Loud Speaker Compartment

The back of the loud speaker compartment is covered in with a sheet of plywood fretted, as shown in Fig. 19, and covered on the inside with gauze and secured with screws. See that the loud speaker leads are fairly tight and that all terminal nuts are tightened up securely.

Accumulator and Battery Compartment

The accumulator and battery compartments are enclosed by small covers screwed in place or held fast by simple turn buttons.

Staining the Case

Stain and polish the case in any selected colours—black walnut for the body and sycamore handles is effective. The set will be found to be sensitive, selective, and to bring in a respectable number of stations at ample loud speaker strength when used with the frame aerial.

Careful adjustment of the reaction condenser and the volume control will generally give very pleasing results.

Pick-up Sockets

The pick-up sockets enable the receiver to be used for electrical reproduction of gramophone records. A B.T.H. pick-up and volume control will convert any ordinary gramophone for the purpose.

Using an Open Aerial

For use on an open aerial, terminals are provided at the back of the case. When used in the ordinary way, connected to aerial and earth, the set will bring in sixty to seventy stations, and on test has picked up American medium-wave stations under favourable conditions.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XXIII—ELECTRICAL MACHINERY

A YEAR or two ago, when mains receivers were a novelty, few listeners bothered to find out what is behind the mains supply. To most of them even now this means that instead of having dry batteries and accumulators connected to one's set, one has a plug on the wall, and that's all there is to it.

To the man who likes to think and find things out, the plug is far from being all-sufficient. He wants to know a little more about it.

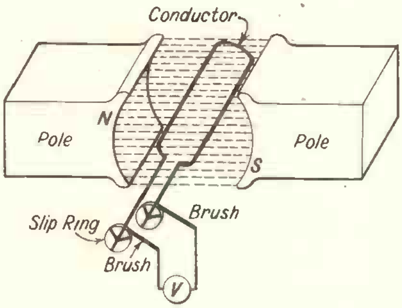


Fig. 1.—HERE WE SEE A SINGLE CONDUCTOR IN THE FORM OF A LOOP, THE ENDS OF WHICH ARE CONNECTED TO METALLIC RINGS (SLIP RINGS).

The outside circuit, consisting of a voltmeter, is connected to the rings *viâ* carbon brushes.

What actually happens is that this mysterious plug on the wall has wires running from it down into the cellar or a convenient nook under the staircase to the electrical meter, which measures the amount of electrical energy consumed by the lighting system in the house and, incidentally, by the valves in the receiver. Near the meter is to be found a fuse box, which carries fuses connected in each separate house circuit.

There are also fuses between the meter and the mains.

The fuses serve as a safeguard for the measuring instruments, lamps and valves, so that if, for some reason, the voltage raises and a larger current is made to flow than usual, the fuse wire, which is designed to carry a predetermined strength of current, will become overheated and will melt, breaking the circuit and thus stopping the heavy current from flowing. A fuse is merely a piece of wire fixed in a porcelain holder and is cheap to replace, much cheaper than lamps or valves.

From the meter, wires are running, usually underground, to the nearest power station, forming part of an extensive system of cables, which supply the whole district.

In the Power Station

The power station, broadly speaking, consists of the so-called *prime movers, i.e.*, engines which cause electrical generators to rotate. Such prime movers can be steam engines, internal combustion engines of the Diesel type, gas engines, and, now-a-days, more often steam turbines. The function of these prime movers is to rotate either the armature of the generator within a stationary magnetic field, or to rotate the magnet system around a stationary armature.

A number of prime movers is thus mechanically coupled to a number of electrical generators, which are used in turn and sometimes all together, in accordance with the demand upon the station, the whole being regulated and controlled from an elaborate switchboard, which carries a number of automatic switches, measuring instruments, and various controlling apparatus.

Two Classes of Electrical Power

The nature of electrical power supplied is divided into two classes—D.C. and A.C. In the case of direct-current supply, the generators are dynamos, and the mechanical power used in the factories in the district is supplied by direct-current motors. With this type of supply, for the purpose of feeding with electrical energy the valves of a receiver, a D.C. battery eliminator is required. The word eliminator indicates clearly that it is something that replaces the ordinary batteries.

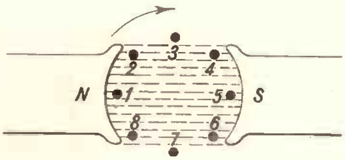


Fig. 2.—CONDUCTOR MOVING IN A MAGNETIC FIELD.

Voltage Drop

Now, the usual voltage developed at the house mains is lower than that generated at the power station. The reason for this is that the power station, being connected to the house by a long line of wires having a considerable resistance, has to drop some of its voltage in the wires, a drop which is numerically equal to the product of the current flowing in the wires and the resistance of the two wires. Thus, it may occur that although the voltage developed at the terminal points of the station is 240 volts, the voltage supplied to the house is only 200 volts, 40 volts being dropped in the line between the station and the house.

How the D.C. Mains Supply Voltage is Lowered

A valve, as you know, requires one voltage for its filament, or heater, another voltage for its anode, and a third voltage for grid bias purposes. A screened-grid valve, or a pentode valve, will require a further and different voltage for its screening grid. There are valves which will work, as far as the filament is concerned, direct from the mains, just like an electric lamp (Oster-Ganz valves). But most of the valves actually in use in this country require a much lower voltage than that supplied by the mains. For this reason, the mains supply voltage has to be lowered, and in the case of a direct supply, it is lowered with the help of resistances, which comprise the so-called D.C. battery eliminator, together with smoothing devices, such as chokes and condensers. This method of lowering the voltage is rather wasteful, as the resistances dissipate electrical energy in the form of heat. This is the reason why there are comparatively few receivers on the market which will work from a D.C. supply.

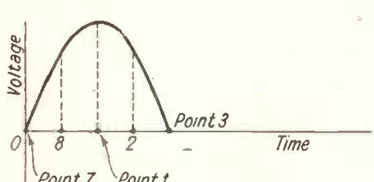


Fig. 3.—GRAPHICAL RERPESENTATION OF THE INDUCED E.M.F.

Reducing A.C. Mains Voltage

The alternating supply presents a much simpler problem from the point of view of reducing the mains voltage, as in this case transformers can be used. While with some types of valves the heater can use alternating current to generate heat, most valves require a direct current for this purpose, and the remaining voltages must also be direct ones. Thus it is clear that some method is required for converting the alternating current into direct one, *i.e.*, some method of rectification. For this reason, an A.C. battery eliminator comprises a step-down transformer, some form of a rectifier, and some form of a smoothing device, again consisting of inductances and condensers, so that the resultant direct current is as free from fluctuations as possible.

Generating A.C. Power with Help of the Alternator

Let us consider, in the first instance, the method of generating A.C. power with the help of the alternator, as the dynamo which generates D.C. power is merely an alternator adapted to a specific purpose.

The scientific fact underlying the action of electrical generators is that if a system of conductors is being moved or rotated in a magnetic field so that the conductors cut the lines of force of the magnetic field at right angles an E.M.F. is generated in the conductors, and if the latter form part of a closed circuit a current will flow in them.

Two Things that are required

Thus it is clear that, in the first instance, what we require is some method of producing a magnetic field and, in the second instance, a system of rotating conductors. It does not matter which rotates, the magnetic field or the conductors, but one of them must be in motion.

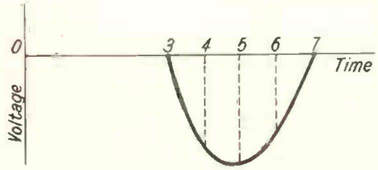


Fig. 4.—The Curve of the Induced E.M.F. Drawn Below the Base Line to show that the E.M.F. has been Growing and Diminishing in the Reversed Direction.

Before we start studying the construction of an alternator, let us see on what depends the E.M.F. produced across the ends of a system of conductors which are rotating in a magnetic field.

A Single Conductor

Let us consider a single conductor in the form of loop, the ends of which are connected to metallic rings (slip rings). Let us connect the outside circuit, consisting of a voltmeter, to the rings *via* carbon brushes, as shown in Fig. 1. For the moment, let us assume that the magnet system is a permanent-magnet system. In studying the magnetic field we shall find that the flux density varies throughout the field, being larger at the centre of the pole and getting weaker and weaker the further we get away from the centre.

When the Maximum E.M.F. is induced

Now, we know that the more lines of force a conductor cuts the greater is the E.M.F. induced in it. Thus it is clear that the maximum E.M.F. induced in the conductor is at, when the latter is moving near, the centre of the poles, and the minimum must be when the conductor is midway between the poles.

A Single Wire in a Magnetic Field

Now let us follow the journey of a single wire in such a magnetic field, as if we were observing the end of the conductor (Fig. 2). Let the wire move in a clock-wise direction, and let us catch it on its journey at the point 7. At this moment the wire is moving parallel to the lines of force, and does no cutting, hence, at the moment there is no E.M.F. induced in it. (E.M.F. equals zero at point 7.) As the wire moves from point 7 to point 8 it progresses through a gradually increasing magnetic field, and therefore is cutting more and more lines of force, and thus has a greater and greater E.M.F. induced in it, from instant to instant.

Thus, as you see, our E.M.F. in the conductor is growing from zero to some gradually increasing value. Between point 8 and 1 the field flux is increasing, being maximum at the point 1, in the centre of the pole. Therefore, as the conductor moves from point 8 to point 1 it has induced in it a greater and greater E.M.F., which reaches its maximum value at the point 1.

With further progress, the conductor travels through decreasing flux, and while it travels from point 1 to point 2, and from point 2 towards the point 3, the induced E.M.F. is steadily decreasing. At point 3 the conductor is once more travelling parallel to the lines of force, and there is no E.M.F. being induced.

The Induced E.M.F. represented graphically

Let us represent the induced E.M.F. through this half circle of travel graphically. All the points on the curve above the base, or zero, line showing the instantaneous magnitude of the E.M.F. (Fig. 3). This graph shows how the induced E.M.F. steadily grows with the progress of the conductor from point to point, from zero to a maximum, and then decreases from this maximum to zero again.

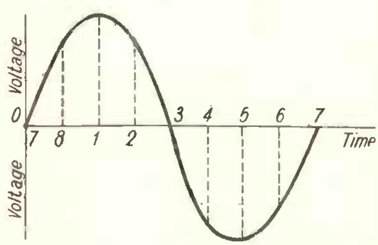


Fig. 5.—A Combination of the Two Graphs Shown in Figs. 3 and 4.

As the conductor moves from point 3 towards the point 4, it starts to cut the weak portion of the flux in the reversed direction (before it was cutting the flux upwards, now it cuts it downwards), and, for this reason, the induced

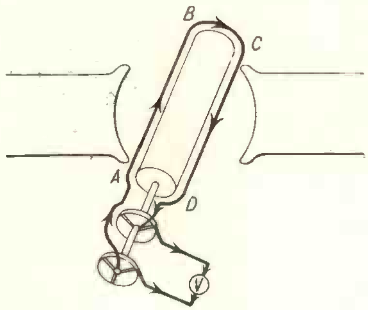


Fig. 6.—Showing how the Current will Flow in one Direction in the Side AB and in the Opposite Direction in the Side CD.

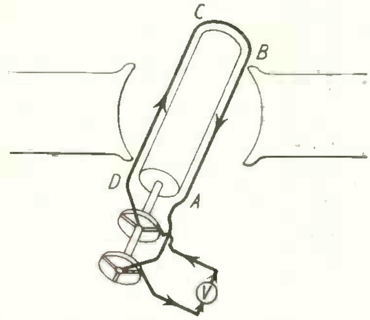


Fig. 7.—Here We see the Current Reversed in the Outside Circuit.

E.M.F. will be reversed in direction. Therefore, as the conductor travels from point 3 towards point 4, and from point 4 towards point 5, the induced E.M.F. will increase from zero to a maximum in the *reversed direction*. Having reached its maximum, with further progress of the conductor from point 5 towards point 6, and from thence towards point 7, it will diminish again till, while the conductor is moving through the point 7, parallel to the flux, it will become zero again.

Reversed Direction

In representing graphically the growth of the E.M.F. while the conductor moves through the second half-circle, in order to show that the E.M.F. has been growing and diminishing in the *reversed* direction, let us draw the curve below the base line, as shown in Fig. 4.

How the E.M.F. varies through a Complete Cycle

Combining the two graphs, we get a graph as in Fig. 5, which shows clearly how the induced E.M.F. varies throughout one single revolution of the conductor, *i.e.*, throughout a complete cycle. It is clear that during each future revolution the same thing will happen, the cycles of changes repeating themselves all the time the conductor is made to revolve.

What the Frequency depends on

During each revolution the induced E.M.F. reverses once. If the conductor moves so as to make only one revolution each second, the frequency with which the E.M.F. is made to reverse is one cycle per second. If the conductor is made to revolve with a speed of a hundred revolutions per second, the frequency of the reversal of the induced E.M.F. will be 100 cycles per second. You see what the frequency of the alternating E.M.F. depends upon ?

How a Varying Alternating Current is Produced

Now let us observe both sides of the conductor loop as it rotates between the poles of the magnet. From Fig. 6 you can see that the current will flow in one direction in the side AB and in the opposite direction in the side CD, the two directions following each other all round the circuit. You will observe that the conductor is mounted on a drum, which is mounted on the same shaft as the two slip rings. Thus the conductor and the slip rings rotate together. When the conductor AB goes over to the other side of the circle, the current in it is reversed with the reversal of the E.M.F., and this also reverses the

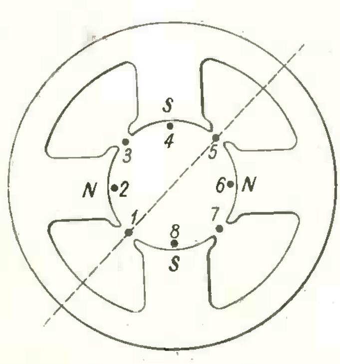


Fig. 8.—Arrangement for Four Poles.

current in the outside circuit (Fig. 7). In this manner the alternator will produce in an outside circuit, connected to its slip rings, a varying alternating current.

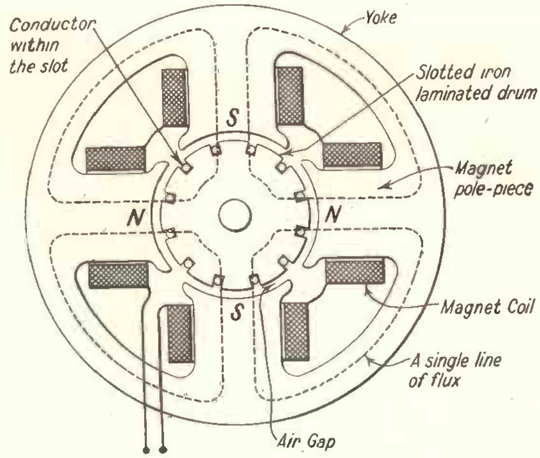


Fig. 9.—HERE WE SEE THE MAGNETIC CIRCUIT.

Four Poles

Suppose now that instead of taking only two poles we take four poles, arranged as shown (Fig. 8). It is clear that with such an arrangement, while the conductor is travelling from point 1 (zero E.M.F.) to point 2 (maximum E.M.F.) to point 3 (zero E.M.F.), to point 4 (maximum E.M.F.), and finally to point 5 (zero E.M.F.), we have a complete cycle of the growth and decay of the E.M.F. in one half of the revolution instead of a whole revolution with only two poles. With four poles we shall have two cycles taking place during each revolution, instead of one. Thus, by doubling the number of poles we have doubled the frequency of the induced E.M.F.

It is clear that this frequency will be further increased by using six poles instead of four, and so on.

Generally speaking, if there are p poles in use and the number of revolutions per second is n, then the frequency of the induced E.M.F. is equal, $\frac{pn}{2}$. The product pn is divided by two because it takes a pair of poles to produce a cycle of changes, and the number of poles divided by 2 gives us the number of pairs of poles.

Accommodating a Number of Loops

Since a certain E.M.F. is induced in one conductor loop, we shall increase the E.M.F. obtained from the alternator if we add the E.M.F.'s induced in a number of loops. In order to accommodate a number of loops, a slotted iron drum is used, the conductors being accommodated within the slots, and are insulated from the iron, the magnetic circuit being as shown in Fig. 9. Since the iron drum has to rotate in a magnetic field together with the conductors, it will have currents induced in it (eddy currents), and for this reason the iron drum is built up from thin laminations.

The drum, together with the conductors, is referred to as the armature of the machine.

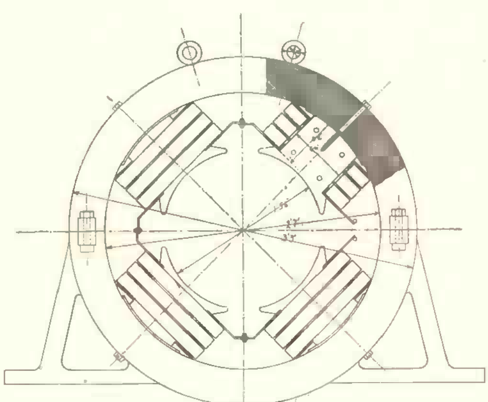


Fig. 10.—THE MAGNET SYSTEM OF A D.C. GENERATOR.

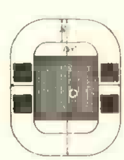


Fig. 11 (Right).—DETAILS OF A SINGLE MAGNET COIL.

What the E.M.F. produced by the Machine depends on

The E.M.F. produced by the machine clearly depends upon the magnetic flux generated by the magnetic system which is usually of the electro-magnet type, *i.e.*, consists of a core with a coil of wire mounted on it, on the number of conductors in the armature, and upon the rate with which these conductors are rotated in the magnetic field. There are also limiting factors, but since design of electrical machinery is outside the scope of this article, we need not go into it, and those who are interested in design of alternators are referred to an excellent book by P. Kemp: "Alternating Current Electrical Engineering," published by Macmillan & Co. Ltd. This book requires a university standard of mathematics.

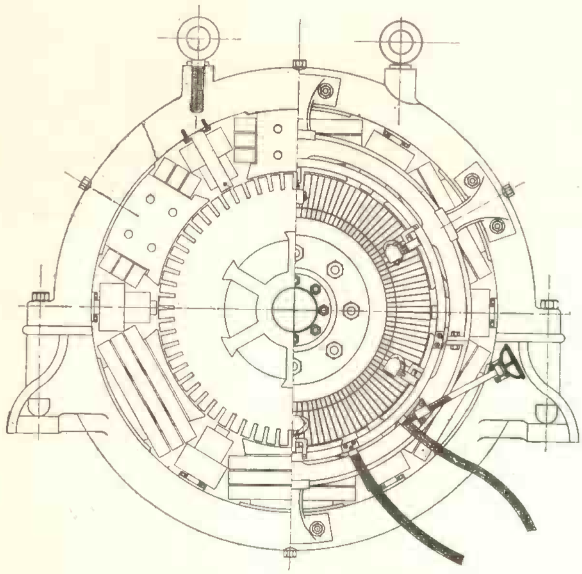


Fig. 12.—The General Appearance and Method of Assembly of a Large Alternator.

In my student days I have designed many a machine, and it may help my readers if I reproduce a number of drawings which will help to show how electrical machines are built up.

In Fig. 10 is shown the magnet system of a D.C. generator, while Fig. 11 shows the details of a single magnet coil.

Fig. 12 gives the general appearance and the method of assembly of a large alternator. Fig. 13 shows a single-alternator magnet pole.

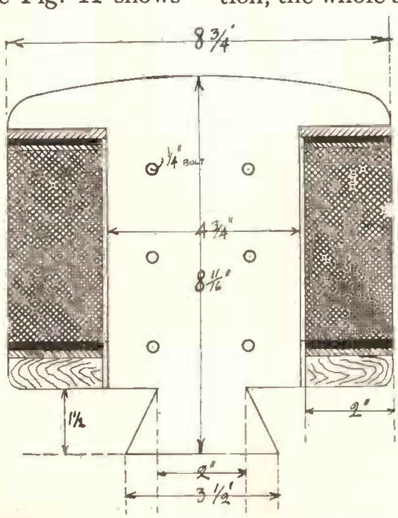


Fig. 13. — A Single Alternator Magnet Pole.

In Fig. 12 you will observe that it is the magnet system that is mounted on the shaft and is therefore rotating. There are 32 poles. The outside of the machine represents the stationary armature, and you can see the armature slots in which the conductors are accommodated immediately above the pole pieces at the top of the left-hand drawing. The right-hand drawing shows the side view of the alternator, from which you can also see the slip rings mounted on the end of the shaft.

Well, it is a similar but single-phase alternator driven by a steam turbine that supplies your set with A.C.

Converting the Alternator into a Dynamo

In order to convert the alternator into a dynamo, all we have to do is to replace the slip rings with a commutator. This consists of a number of copper segments. Each copper segment is insulated from the next copper segment by a layer of insulation, the whole assembly being ground to a common level. Two or more brushes rest upon the commutator for the purpose of making contact with the outside circuit.

What the Commutator does in the Case of a Dynamo

In order to see clearly what the commutator does in the case of a dynamo, let us replace the slip rings in Figs. 6 and 7 by two commutator segments (Figs. 14A and 14B). If you compare these with Figs. 6 and 7 you will see that the commutator

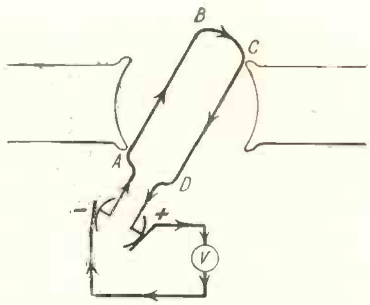


Fig. 14A.—Here We See a Coil A.B.C.D. connected to Two Commutator Segments.

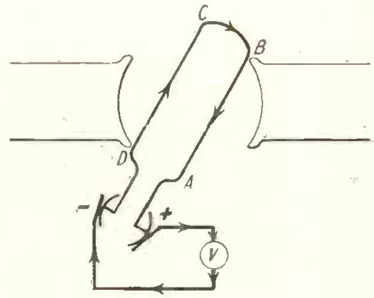


Fig. 14B.—The Coil has now turned Through half a Revolution.

causes the current to flow in the same direction all the time in the outside circuit.

Each Brush has a Definite Polarity

Thus, in the case of a dynamo, each brush has a definite polarity, one being positive and the other being negative. For this reason we can show graphically a dynamo cycle of events, as in Fig. 15. This clearly shows that the current delivered by a dynamo is not a steady current of constant value, but varies, always in the same direction, from zero to maximum, then to zero, then again to a maximum (as before), and to zero again. In the case of, say, a six-pole machine, we shall have three cycles of variations in one revolution. Graphically this can be shown as in Fig. 16, and is clearly equivalent to some average current in the same direction. Now, in the case of a machine performing 600 revolutions per minute *i.e.*, ten revolutions per second with six poles, the frequency will be 30 cycles per second. The greater the frequency of the machine the nearer the average current is approaching the maximum value, which is occurring with the increase in frequency more and more often during the second.

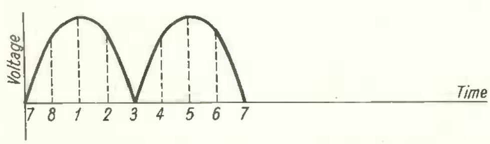


Fig. 15.—A Dynamo Cycle of Events Shown Graphically.

Necessity for Smoothing Devices

Well, this is how we obtain our D.C. supply and, having realised that the E.M.F. delivered by a dynamo is not exactly a constant current as we obtain from a cell, you will realise the necessity for smoothing devices in the D.C. eliminator. The individual pulses being in the same direction and of the same amplitude, give a steady average current which approaches very near in its effect to that delivered by a cell.

Magnetic Effect

Its magnetic effect is a steady magnetic field which does not move appreciably in space, and therefore a transformer cannot be used for stepping down the voltage.

From the physical point of view, what the magnetic field does both in the case of alternators and dynamos is to move electrons within the conductors, as the latter swing past the poles and make first one end of the conductor rich in

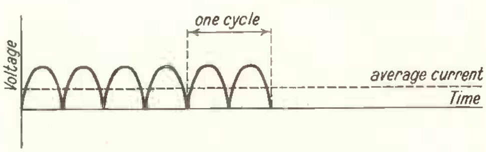


Fig. 16.—Graphical Representation of Three Cycles of Variations in one Revolution of a Six-Pole Machine.

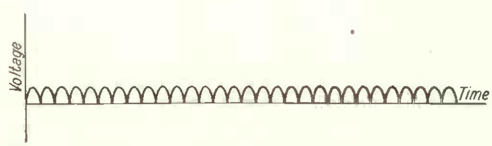


Fig. 17.—Showing the Ripples on D.C. Supply. These have to be smoothed out in D.C. Eliminators.

electrons at the expense of the other end, and then the other end at the expense of the first end.

Electronic tides are caused in the conductors, and they are the cause of what we call the E.M.F., and the reason why currents are flowing in closed circuits.

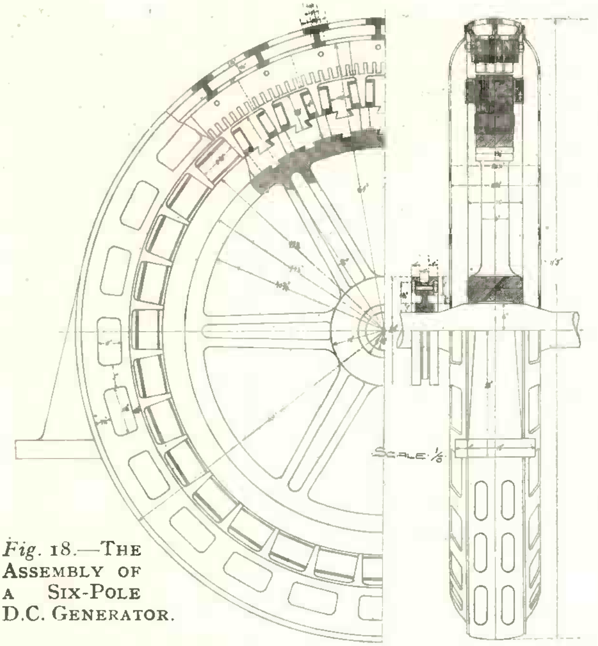


Fig. 18.—THE ASSEMBLY OF A SIX-POLE D.C. GENERATOR.

Assembly of a Six-pole D.C. Generator

In Fig. 18 you can see the assembly of a six-pole D.C. generator. In this case the magnet system is stationary and the armature is being rotated. In between the poles you see additional pole pieces, which are called inter-poles, and which are used in order to reduce excessive sparking between the brushes and the commutators.

The presence of the interpoles does not alter our previous argument as regards the function of the machine.

Now, these are the main types of electrical generators. There are also the so-called high-frequency alternators which were used for transmitting purposes before the advent of the oscillating valve.

The transformer, which is a machine for stepping up or stepping down voltages and currents, I have discussed elsewhere, and all that remains now is to investigate the principle of operations of electrical motors.

Principle of Operations of Electrical Motors

In the case of a dynamo, if instead of connecting to the commutator an outside circuit for utilisation of the electrical energy generated by the dynamo, we feed the armature conductors with electrical current, say from another dynamo (rotated by a prime mover), the current flowing in the conductor will produce a magnetic field of its own, so that we shall have two magnetic fields in existence, one due to the magnet system and the other due to the current flowing in the armature conductors (Fig. 19). The two fields will repel each other. Since the magnet system is stationary, and is bolted to the floor, it cannot move, and the only thing that can move is the armature mounted on the shaft. So it begins to rotate, and will make another piece of machinery, coupled to it mechanically, rotate as well, and perform work.

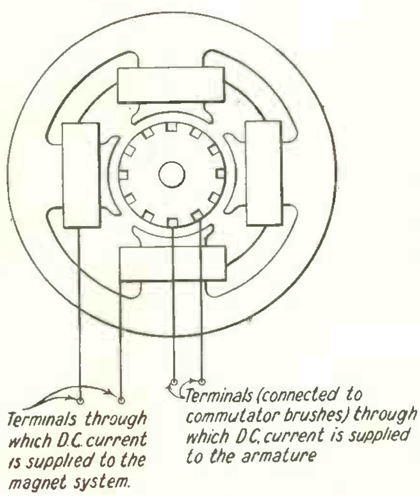


Fig. 19.—THIS SHOWS TWO MAGNETIC FIELDS IN EXISTENCE.

One due to the magnet system, the other due to the current flowing in the armature conductors.

The D.C. motor is practically of the same construction as the dynamo, and also possesses a commutator.

How Induction Motors are Constructed

Now this leads us to another thing. Here we have created a magnetic field by passing a current through the armature. We can do away with the magnet system, and have instead of it another armature through which a current is flowing, and have two fields, again clashing with each other, so that the armature that can rotate (called the *rotor*) performs the revolution, and the stationary armature (the stator) remains fixed in position.

This is how the so-called induction motors are constructed. In Fig. 20 you see a design of such a motor. There is no magnet system at all, but merely two slotted drums of iron (both laminated), carrying conductors. Both the stator and the rotor windings are fed from an outside source (in the case of a magnet system of a dynamo or an alternator it is only the coils of the magnet system that are fed wholly or partly from an outside source), and the resultant magnetic fields repel each other and cause the rotor to rotate. Such machines are very simple in construction, and are very popular in certain industries.

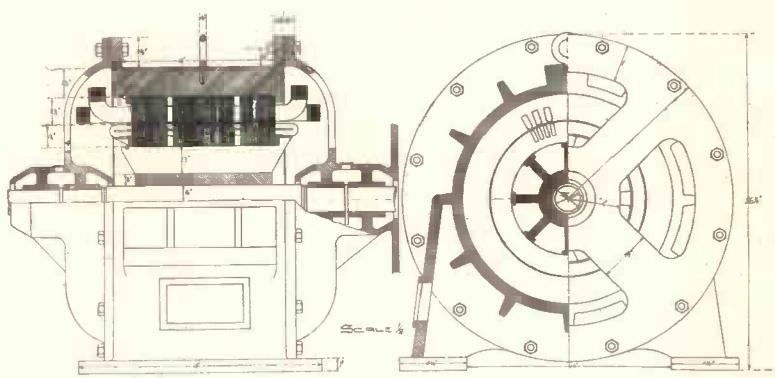


Fig. 20.—How an Induction Motor is Constructed.

Combination of Dynamos, Motors and Alternators

It remains now to consider the combination of dynamos, motors and alternators. It may happen that having a direct supply, you want an alternating one. This is obtained by coupling a D.C. motor to an alternator, or mounting them on the same shaft. In this way we feed the motor from the D.C. supply that is available, and the motor in rotating will make the alternator rotate and thus deliver an A.C. supply. This is called a *rotary convertor*, and is often used in wireless reception for using an A.C. receiver from D.C. mains with the help of the convertor.

How a D.C. Supply is obtained when only A.C. is available.

There may be another problem. A D.C. supply may be required when only A.C. is available. This can be overcome by coupling an A.C. motor to a dynamo. In the case when there is no mains supply available, it is possible to have a motor-generator set which consists of a D.C. motor armature and a dynamo armature mounted on the same shaft. The motor is fed from a bank of accumulators and is thus made to rotate the dynamo which supplies the D.C. power.

This covers the survey of electrical machinery that is of interest to us from the point of view of wireless reception and transmission.

Design of this machinery is a fascinating subject, and is not at all difficult, provided that one has a thorough grasp of the theory of electricity and magnetism, and a sufficient knowledge of mathematics. (The knowledge of algebra and trigonometry is indispensable.)

Useful Books to Study

Those who are interested in the subject, and wish to see how a machine is designed, should read "Continuous Current Machines," by Dr. S. P. Smith (Benn Bros. Ltd.).

TONE CONTROL

By FRANK PRESTON

ANYONE who has not had the opportunity of hearing a set with which the tone of the loud speaker may be varied from "brilliant" to "mellow" at will can scarcely appreciate the tremendous advantages which tone control confers; those who have used such a set would never dream of going back to one of the old type.

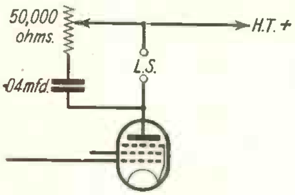


Fig. 1.—The Usual Method of Reducing High-Note Response.

We all know that it is practically impossible to obtain "perfect" loud speaker reproduction, especially with the average domestic receiver, so for the present we must aim at the next best thing, namely, "pleasant" reproduction. The difficulty is, however, that what is pleasant to one person may be distinctly unpleasant to another. What can be done, then, to please everybody? The answer is very simple—fit a tone control.

Uneven Frequency Response

This is just one advantage of tone control, but there are many others of perhaps greater importance. There is hardly any component in a wireless set that responds equally well to all frequencies within the harmonic range which we can roughly describe as extending from 32 to 9,000 cycles per second. For instance, a selective tuner scarcely recognises frequencies above 4,000 cycles or so; most low-frequency transformers neglect frequencies below 100 cycles; a pentode valve gives far more prominence to frequencies above some 2,000 cycles; some loud speakers give plenty of bass and very little treble, whilst others behave in an entirely opposite manner.

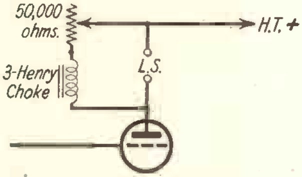


Fig. 2.—Low-Note Emphasis can be Cured by Connecting a L.F. Choke across the Speaker Terminals.

We can see quite clearly from this that the design of an average home-built set from the point of view of "quality" of reproduction is very often a matter of "hit and miss." But if we can fit some device to the loud speaker or another part of the audio frequency circuit by means of which the bass or treble can be strengthened or attenuated as desired, we can make up for most of the shortcomings of the set itself.

Tone-Balance

There is another point which will have a particular appeal to those who indulge in long-distance reception. However powerful the receiver may be, the tone-balance, as one might call it, of various stations differs enormously. One station sounds dull and "boomy," and another quite "screechy." In other words, one has too much bass and the other an excess of treble. If we have a ready means of varying the frequency response of our receiver, we stand a good chance of getting enjoyable reception from any transmitter.

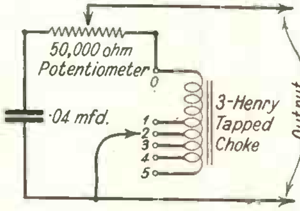


Fig. 3.—A Complete Tone-Control Circuit; by Adjusting the Potentiometer High-note or Low-note Attenuation can be Produced as Required.

Heterodyne Whistles

Tone control offers yet another advantage of vital importance at the present time, *i.e.*, the elimination of high-pitched heterodyne whistles which occur when two stations are operating on very near wavelengths. The heterodyne notes generally have a frequency of between 5,000 and 9,000 cycles, and thus by reducing the response of our set to frequencies of that order, the whistles can be sufficiently reduced in intensity to make them inaudible. Of course, by eliminating the heterodynes we must also lose a little in the way of higher musical notes.

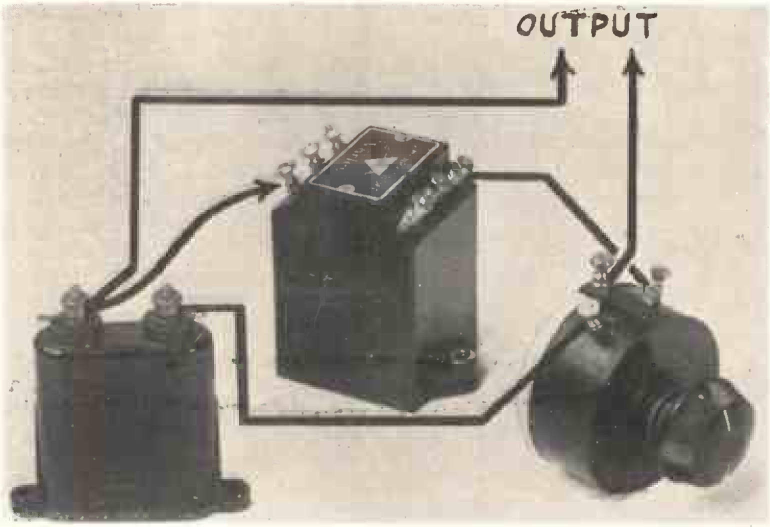


Fig. 4.—The Simple and Convenient Tone Control Arrangement.

Principles of Tone Control

I do not think there will be any reader who does not now agree that tone control is definitely worth while, and, in fact, almost indispensable to a modern broadcast receiver. In theory, tone control is perfectly simple, and from a practical standpoint it offers no difficulty whatever. The whole thing is based on two facts which have been known to, and exploited by, telephone and broadcasting engineers for a very long time, namely (1) a condenser offers less impedance to high- than to low-frequency currents. (2) A low-frequency choke offers less impedance to low- than to high-frequency currents.

Fixed Condenser across Loud Speaker

If you connect a fixed condenser across the loud speaker terminals of your set the "pitch" of the music will be lowered, since the condenser will allow high notes (or frequencies) to leak away without actuating the speaker. Increase the capacity of the condenser and more high-note loss will occur, or reduce the capacity and the loss will not be so great. It can be seen that if a variable condenser were used the amount of high-note cut-off could be altered. As, however, the capacity requires to be between about ·01 and ·05 mfd, an ordinary variable condenser is out of the question.

Condenser and Variable Resistance

Fortunately a similar result can be obtained by connecting the condenser in series with a variable resistance, and this is the method we apply in practice. A high-note filter is often employed with a pentode valve, and it is connected as shown in Fig. 1; the condenser has a value of ·04 mfd., and the resistance is of 50,000 ohms maximum rating. The very same arrangement can be used with any set which gives over-emphasis to the treble, whether the last valve is a pentode or not.

Reducing the Bass

When the bass is too prominent an improvement may be effected by connecting an iron-cored choke across the speaker, as shown in Fig. 2. The choke should have an inductance of from 1 to 3 henries, and therefore if it were used alone it would probably cut out nearly all the sound from the speaker because, due to its comparatively low resistance, it would practically "short-circuit" the loud speaker windings. Consequently, it must be wired in series with a variable resistance as shown.

When the resistance is set to its full value the choke will have no effect, but as the resistance in circuit is reduced, more and more current will pass through the choke and low-note response will progressively be reduced. To take full advantage of this scheme it is preferable to employ a tapped choke, so that the optimum inductance can be chosen experimentally.

Both of the tone-control systems mentioned can be applied to nearly any audio-frequency circuit; they may be connected in parallel with the loud speaker, primary winding of an L.F. transformer or with a gramophone pick-up. As a matter of fact, some L.F. transformers (particularly the Varley "Rectatone"), are fitted with a small choke, and only require the addition of a variable resistance to make them suitable for tone control.

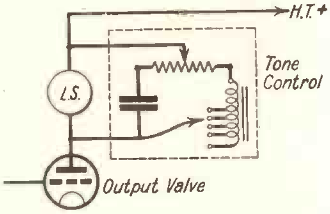


Fig. 6.—Tone Control with a Directly-fed Loud Speaker.

Making a Tone Control

So far we have only considered methods of reducing either low- or high-note response, but to achieve real tone control we must be able to regulate the response at both ends of the scale as, and when, required. This we can do by connecting a fixed condenser, tapped 3 henry choke and 50,000 ohm potentiometer, as shown in Figs. 3 and 4. The choke is a Varley "Three Henry Tapped Choke" (specially designed for this purpose), the potentiometer, a Varley type "CP159," and the condenser, a Dubilier type "BB."

And Using it

To use the tone control, connect the two leads marked "output" across any audio-frequency circuit. Probably the

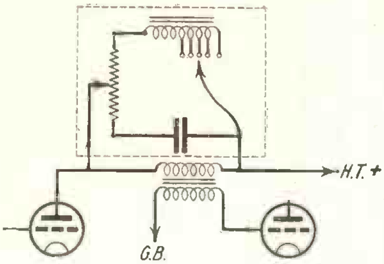


Fig. 5.—The Tone-Control Circuit shown in Figs. 3 and 4 Connected across the Primary Winding of a L.F. Transformer.

best position is in parallel with the primary winding of the first low-frequency transformer, as shown in Fig. 5. As can be seen in the photograph, the choke has six terminals marked "0," "1," "2," "3," "4" and "5"; terminal "0" is in contact with one end of the winding, whilst the other terminals provide tappings at ·5, 1·0, 1·5, 2 and 3 henries respectively.

Using the Circuit with an L.F. Transformer

When using the circuit with an L.F. transformer it is generally found that optimum results are obtained by connecting to terminals "0" and "4," but the other tappings should be tried to find which is best for the particular transformer in use. The aim should be to find the tapping which gives most low-note attenuation combined with a minimum reduction in overall volume.

When the potentiometer is set to its midway position both the condenser and choke are more or less isolated, and therefore their effect is practically nil.

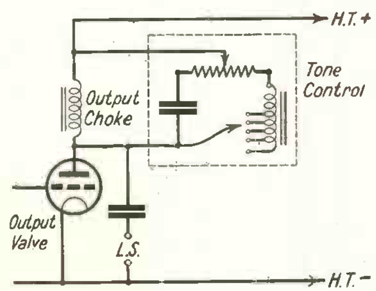


Fig. 7.—A Tone-Control Circuit in use with a Set having a Choke-capacity Output Filter.

But as the knob is turned either clockwise or anti-clockwise the condenser, or choke, is brought to bear upon the circuit, and in consequence the tone is varied from "mellow," or "bass," to "brilliant," or "treble."

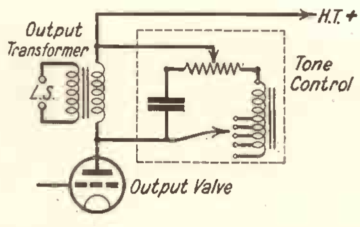


Fig. 8.—When the L.S. is Fed Through an Output Transformer the T.C. Circuit should be Joined Across the Primary.

In the Loud Speaker Circuit

The same tone control arrangement can be connected in the loud speaker circuit, as shown in Figs. 6, 7 and 8. In Fig. 6 it is assumed that a balanced armature, or similar type of speaker, is wired directly in the anode circuit of the output valve; Fig. 7 shows the connections when a choke-capacity filter is employed, and the connections of Fig. 8 apply to a set using an output transformer. If the tone control were used with a mains receiver taking a very high anode voltage it would be preferable to isolate the tone control circuit by wiring it in series with a large-capacity (1 to 4 mfd.) condenser, as shown in Fig. 9. The condenser prevents D.C. current from passing through the choke whilst at the same time providing an easy path for the audio frequencies.

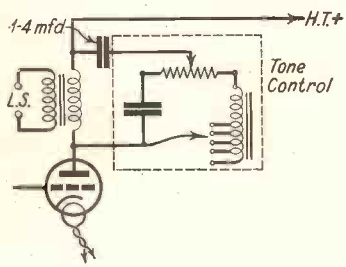


Fig. 9.—When Using the Tone Control with a Valve Taking a very High Anode Voltage, it is Preferable to Isolate it from the D.C. Supply by Means of a Large-capacity Condenser.

With a Gramophone Pick-up

Tone control can be applied to a gramophone pick-up, as indicated in Fig. 10, but in this case it might be necessary to use a potentiometer of different value to that previously specified. A resistance of 50,000 ohms is quite suitable for use with a low-resistance pick-up, such as the B.T.H., but the value should be increased to at least 250,000 ohms when a high-resistance instrument, for example a Marconiphone, is employed. If the potentiometer were of too low a resistance it would cause an appreciable loss in volume.

Tone control is particularly useful with a pick-up because it enables the bass, which is of necessity somewhat curtailed in the recording process, to be brought up to good strength. At the same time it makes possible the elimination of needle scratch.

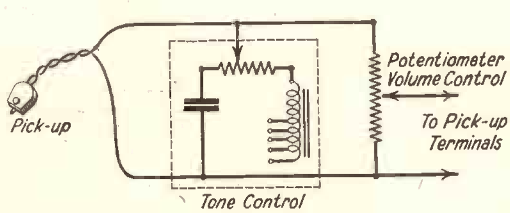


Fig. 10.—The Tone Control Fitted to a Gramophone Pick-up.

Tone Control Transformers

The circuit described above is an excellent one for adding to any existing receiver, but if a new set were being constructed it would be cheaper to employ a special tone control transformer instead. This would replace the normal low-frequency transformer, and should be connected in the same way, except that an additional potentiometer would be required. The best-known tone control transformer on the market is the "Multitone," and this consists of ~~an ordinary low-frequency transformer, a suitable choke and fixed resistance, all contained in the same case.~~ * Messrs. Lissen also make a "tone compensator," which can be connected to their "Hypernik" transformer. This latter is a small unit containing a choke and condenser, and requires only the addition of an external potentiometer.

* "a straightforward transformer, the tone control being obtained by a principle which is the multitone patent, and is a matter of transformer winding pure and simple."

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

MAKING A SIGNAL GENERATOR

TELEVISION

SOUND RECORDING AT HOME

METERS AND METER FAULT FINDING

1/-

Part 30

IN 32 WEEKLY PARTS

PART 30.

WIRELESS THEORY MADE PLAIN

By RALPH STRANGER

SECTION XXIV—TELEVISION

I DO not hesitate to say quite definitely that television is an accomplished fact. In the past there has been a great deal of scepticism as regards the results obtained by Baird and others, and difficulties have been placed in the way of the early pioneers of this new branch of science by people who should have known better. Many of the critics did not even bother to investigate the progress made but merely scoffed as it seemed to them that the "quantities were against Baird."

The same mysterious quantities were against Galileo, Maxwell, Hertz and Marconi. How some people laughed at communication without wires! It is rather unfortunate that we have always with us the "scientific" know all, who is probably the most ignorant of men. Never has the old adage: "A little knowledge is a dangerous thing" been so clearly demonstrated as in the case of television.

What the Amateurs have done

Why a pioneer should always be met with scepticism, if not with derision, is a little obscure, unless scientists as a class are the most conservative people on earth. But, it is fortunate that our so-called "amateurs" or "amateur experimenters" refuse to be disheartened by the heavy dicta of solid "science," and having grasped a new principle merely go ahead and experiment till "science" sits up and takes notice. The same thing happened with short waves. When broadcasting came into existence and the medium waves, the favourite domain of amateur transmissions, became necessary for use in the new art, the "amateurs" were given short waves to experiment with, short waves which were pronounced to be "impossible" for long-distance communication. Look at the short waves now. Empire broadcasting!

Broadcasting House takes television seriously. Transmissions are taking place daily and a new technique is being rapidly developed. The time is not long distant when television receivers will be as commonplace as wireless receivers, and already a television press is rapidly springing up and books are written on the subject in ever-increasing numbers. The new art is forging ahead and there is nothing to stop it now, not even the cinema interests, which are frightened of it. The old story all over again. When broadcasting came into being it frightened the gramophone interests, the theatre proprietors, and even the newspapers and book publishers were nervous of it. Broadcasting benefited all these interests, much to their surprise, and so will television.

Principles Underlying Television

In a year or two you and I will be using a televisor daily, and for this reason let us see what are the principles underlying this wonderful new art. Vision is a natural phenomenon. Light rays fall upon the retina of the eye, certain chemical processes take place and the

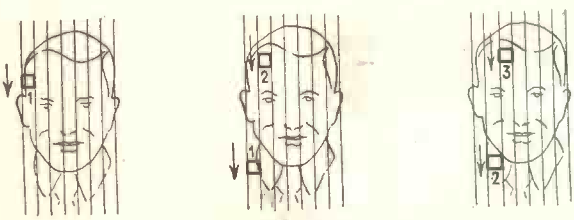


Fig. 1.—Showing how the Lenses in the Baird Television System are arranged.

When the light shines upon the bottom portion of strip one, the next beam is ready to strike the top portion of strip two, and so on.

nerves are made to transmit sensations so received to the brain, which interprets such sensations in the form of a picture.

Wavelengths of Light Rays

Light rays are electro-magnetic waves of short wavelengths which range between 0·0004 and 0·00072 millimetre. The lower wavelength gives us the violet-coloured light and the higher wavelength the red, the intermediate primary colours lying between these limits. The white light is a combination of these wavelengths and can be split up into its component parts with the help of a prism owing to the fact that not all light rays pass a medium with the same speed, some of them are retarded more than others and thus the apparently white light is split up into a coloured *spectrum* with which we are all familiar, if not from the point of view of spectroscopy, from the appearance of the rainbow.

Why we are able to see

The reason why we see at all is that light rays fall upon different objects and are *reflected back* and absorbed with varying intensity, so that not only do we see light and shade but also different colours. But the most important fact is that an object does not reflect light rays uniformly.

The Reflecting Surface

The reflecting surface, such as a human face, for instance, is not a plain reflecting surface but consists of hollows and prominences so that each small portion of the face reflects light with considerably varying intensity. Thus, if we investigate each small portion of any object we shall find that each portion will reflect a beam of light of its own differing from the beam of light of the next portion.

How a Succession of Light Rays is Produced

We can say, therefore, that every small portion of an object sends out to the eye looking at it a large number of light rays of differing intensities. In the ordinary way the eye receives all these messages simultaneously. But suppose that we cover the object and by some means or other uncover in quick succession, in some definite order, portion after portion, covering up each portion immediately after it has been scanned by the eye. In this manner we shall have a succession of light rays reaching the eye, each ray differing in intensity from its fellow.

Persistence of Human Vision

Human vision persists. This property of the human eye made cinematography possible. A rapid succession of still pictures is being unrolled before our eyes, and as one still picture slides out of view and is replaced by another, owing to persistence of human vision, the old picture is still being dealt with by the brain while the new picture arrives. The brain thus deals with pairs of pictures and the whole succession of still pictures becomes an animated continuous picture as far as the brain is concerned. The same thing will happen if we explore quickly the small portion of an object. Vision will persist, and if the exploring is done quickly enough we shall see the object as a whole, the eye being unable to differentiate between the successive flashes of light, provided that they occur at least every tenth of a second.

A Chance for Experimenters

It is clear that if we want to send any message across the ether in the form of electromagnetic waves, waves which can be picked up by an aerial and dealt with by a receiving apparatus of some description, we must have electrical currents. Although light rays are rapid trains of electro-magnetic waves, we have not yet the means of tuning in such waves directly as we tune in the larger wavelengths. (Now, then, experimenters, here is your chance; see if you can devise a circuit to deal with waves of the order of 0·0004 millimetre and thus interpret directly light in the form of electrical currents—remember that we can already deal with waves below a centimetre—the micro ray), but it is clear that these waves somehow or other have to be interpreted in the form of electrical currents.

Interpreting the Light Flashes into Electrical Currents

We already know that it is possible to analyse a visible object as a succession of light rays, flashes of light occurring one after another as we can the object by uncovering for an instant portion after portion, and therefore if we had some device that would interpret this rapid procession of light flashes of varying intensity into corresponding electrical currents we have solved our problem. This means that we have to find a conductor which would vary its resistance with the variations in light.

Is such a conductor a physical possibility? Well, since light rays are electro-magnetic waves, and electro-magnetic waves are capable of influencing electrons in the surface atoms of conductors, there is no reason why a wave of 0·0004 millimetre wavelength should not produce an effect similar to that produced by a much larger wavelength, even if that effect be infinitely smaller.

Fig. 2.—A TYPICAL PHOTO - ELECTRIC CELL.

This is the Osram C.M.G.8 photo - electric cell.

Selenium

As a matter of fact, it is possible to vary the resistance of a conductor with the variation of intensity of illumination. There is a substance called selenium which has a very large resistance in the dark and diminishes its resistance with the increase in illumination. Having this property it can act as an interpreter of light flashes into corresponding strengths of electrical currents. When tried for television purposes selenium proved to be unsatisfactory as it is a little slow in its interpreting.

Photo - electric Cell

For this reason another piece of apparatus has been devised which consists of two electrodes enclosed in a glass bulb. One of the electrodes is made of a substance very rich in electrons. When a source of an E.M.F. is connected across the two electrodes, the electrode already rich in electrons is made still more negative and the other electrode positive. There is a tendency therefore for electrons to pass on from the negative electrode to the positive one and so flow through the apparatus in the same way as they flow through a valve. But in a valve the electrons have an incentive to flow as the filament is at a high temperature and electrons are shot off into space. In our present arrangement there is no heated filament. And this is where light rays come into play. The arrangement in question is called a photo-electric cell.

How the Photo-electric Cell is Constructed

The inner surface of the bulb of the photo-electric cell is coated with a substance whose atoms have a large number of "planetary" electrons; a portion of the bulb is, however, left uncovered, forming a small window in the bulb. This inner coated surface represents the negative electrode. In the middle of the bulb is placed a tungsten loop covered with a fine gauze of wire, insulated from the inner coating of the cell. This loop represents the positive electrode.

Now, when the source of E.M.F. is connected across the cell electrodes, no current will flow through the cell provided the latter is kept in the dark, but as soon as

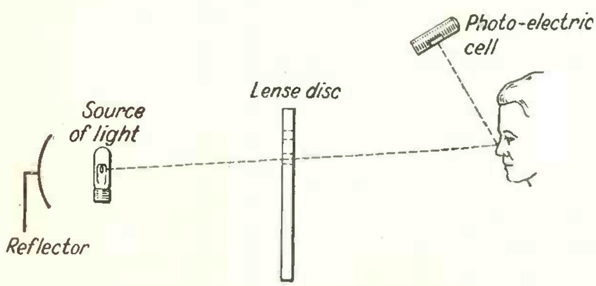


Fig. 3.—SHOWING HOW A SUCCESSION OF CURRENTS OF DIFFERING STRENGTH PASSES THROUGH THE PHOTO-ELECTRIC CELL AND ITS CIRCUIT.

light begins to shine upon the inner coating, electrons get knocked out from the coating and are attracted towards the positive electrode. In this manner a current is made to flow through the cell, its strength varying with the intensity of the light rays falling upon it. For each particular intensity of the ray there will be a corresponding and proportional current through the cell and therefore through the external circuit connected to the cell. Well, this gives us a means of interpreting light flashes in the form of corresponding electric currents, and once we have anything interpreted in the form of electrical currents, we know how to deal with them.

The Next Problem

Our next problem is to arrange for the instantaneous uncovering and the immediate covering up of a small portion of the object so that we get a distinct, rapid and consecutive succession of light flashes, each flash illuminating the photo-electric cell and producing in it a corresponding current.

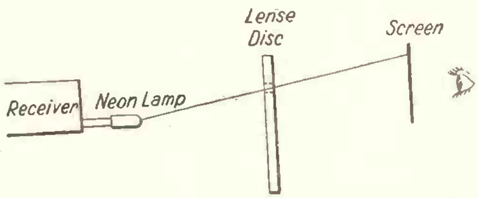


Fig. 4.—HERE WE SEE THE ARRANGEMENT AT THE RECEIVING END.

The Baird Televisor

Baird, in his original apparatus, solved this problem in a very ingenious manner. He designed a rotating disc carrying a number of lenses arranged in the form of a spiral. These lenses are so arranged that at any one instant only one lens passes and focuses a ray of light from a powerful source upon a tiny portion of the object, and as lens after lens thus comes into action the object is successively illuminated in narrow strips from top to bottom, and so that when the light shines upon the bottom portion of strip one, the next beam is ready to strike the top portion of strip two, and so on (Fig. 1). With each successive illumination of a small portion of the object each portion sends its reflected beam to the photo-electric cell in turn, and so a succession of currents of differing strength passes through the cell and its circuit (Fig. 3).

How the Whole Object is Scanned

Thus, it is clear that in the first place we have a strong source of light which is focussed upon the object with the help of lenses in the rotating disc. As the latter rotates lens after lens rapidly "uncovers" a tiny portion of the object upon which a strong light is focussed for a small fraction of a second, each tiny portion sending its reflected ray upon the photo-electric cell. In this manner the whole object is scanned and each portion of the picture is interpreted in the form of a corresponding strength of electrical current. The currents passing through the cell are amplified in the usual way and are superimposed upon the carrier current in the aerial in the same way in which microphone varying currents are superimposed.

Modulating the Carrier Wave with the Photo-electric Cell

Thus, we modulate the carrier wave with the help of the photo-electric cell impulses and can send out a modulated electro-magnetic wave bearing the characteristics of the light reflections from the televised object. For each light flash we have a definite strength of current and therefore a corresponding radiated electro-magnetic wave.

At the Receiving End

When this wave encounters a receiving aerial it will induce in it currents similar to those which have been flowing in the transmitting aerial, and when the receiver has dealt with the potentials produced by those currents we shall get in the output circuit currents of the same nature as those flowing through the photo-electric cell. And, if now, we can pick up these currents and interpret them into light flashes once more we shall obtain flashes identical with those reflected by the tiny portions of the scanned object.

How are we going to do this ? How can we interpret an electric current as a flash of light? Easy enough! We do this every day in our electric lamps. Thus, it is clear that if at the output end of the television receiver we place some form of an electric lamp, each impulse of current of different strength will produce a characteristic flash of its own. In this manner we shall obtain precisely the same succession of flashes that we had at the other end falling upon the photo-electric cell. We have got our flashes back again!

Placing the Flashes on a Screen in the Correct Order

Now comes the next problem of placing the flashes on a screen in the same order as they have been flashed off the scanned object. A disc identical in design with the disc at the transmitting end and rotating with the precise speed of the other disc is brought into action. Now, the flashes from the lamp connected across the output circuit (a special neon lamp is used for this purpose) pass through the lenses of the rotating disc, which now rotates so as to place the first flash in its exact position at the top of the first strip, and so flash after flash till the whole picture has been reassembled. Although these flashes succeed each other in turn, owing to the persistence of human vision, the flashes are retained by the eye long enough to give the eye the whole picture. The arrangement is as shown in Fig. 4. The whole scheme of events is depicted in Fig. 5.

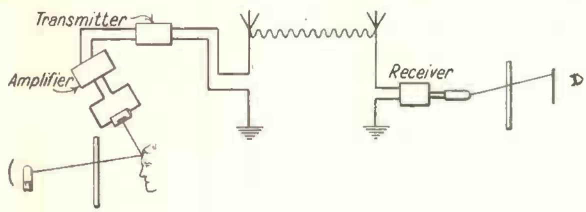


Fig. 5.—The Whole Scheme of Events shown diagrammatically.

How the Discs are Rotated at the Same Speed

The discs introduce a problem of rotation at the same speed and this synchronisation of speed, to give it a scientific name, is achieved with the help of a regulating device incorporated in the televisor, the speed being predetermined.

The Mirror Drum

The rotating disc has been employed by Baird in his first model but now it is replaced by a mirror drum which carries a number of mirrors, each of which is fixed at a different angle. Such a drum acts in a manner similar to the disc by throwing a beam of light at the transmitting end on to portion after portion of the scanned object, the reflected succession of rays falling upon the photo-electric cell as before. At the receiving end the same thing happens. The light from the neon lamp falls upon the mirrors rotating before the beam and they reflect the neon lamp beams in their proper succession upon the screen.

Other Systems of Television

I do not propose to go into the construction of the televisor as this has already been covered in another part of this work, but I should like to bring to the attention of my readers other systems of television which are being developed abroad and in this country. There is an exciting race for the most simple and the least expensive method of television at the listener's end. It should be stated that at the moment two receivers are required, one for ordinary listening purposes and the other for television purposes, and therefore there are two aerial systems at the receiving end. It may be that this arrangement will be greatly simplified in the near future and a single piece of apparatus will do the two jobs.

Ruhmer's System

As far as 1901 back Ernest Ruhmer attempted to use a screen of selenium cells, insulated from each other, so that the varying intensity of illumination, formed by reflected light from various parts of the surface of the object, produced in each cell a current of its own. Each cell was connected separately to a corresponding source of light on the receiving screen. The current flowing in each cell produced its own illumination and thus the picture could be reconstructed by a number of point lights. This system proved to be impracticable.

Szczepanik's System

A more practicable system has been devised by Szczepanik, who used one selenium cell, and with the help of vibrating mirrors made the image travel in front of the cell in a zig-zag path, effecting something similar to modern scanning.

Belin and Holweck's System

Belin and Holweck used a method similar to Szczepanik, as far as scanning is concerned, but the current passing through a photo-electric cell was made to control the flow of electrons in a cathode ray tube (oscillograph), the electron stream being moved across a fluorescent screen with the help of magnetic fields in the same way in which the mirrors were zig-zagging at the transmitting end. This also proved to be impracticable.

Invention of the Mirror Drum

It was Dr. Alexanderson, of America, who introduced the idea of the mirror drum, each mirror set at a different angle, now adopted in modern television. He also used the early method of building up a mosaic of cells at the transmitting end and using a corresponding number of point lights at the receiving end, in order to rebuild the picture.

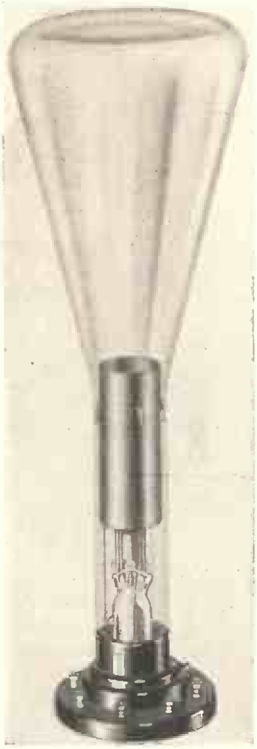


Fig. 6. — A Cossor Cathode Ray Oscillograph.

The oscillograph has lately been coming to the fore in television.

The Oscillograph in Television

Lately, the oscillograph has been coming to the fore in television and there are persistent rumours that something good is being done in this direction. It may not be out of place, therefore, to make our acquaintance with this piece of apparatus so that we can follow intelligently any new developments that may take place.

Construction of the Oscillograph

The modern oscillograph has been developed from the cathode ray tube. The mysterious cathode ray is merely a stream of electrons from the negative electrode towards the anode. On the modern oscillograph a heated filament is used for the electron emission. The tube is filled with rarefied gas, and when a large difference of potential is applied across the electrodes an electric discharge takes place and electrons stream through the tube. If this electronic beam is met with a fluorescent screen, the point of impact, will glow. It is possible to deflect this electron stream and make it move with the help of a magnetic field. As the electron stream moves the glowing point on the fluorescent screen will also move, giving a visual demonstration of the movement of the stream. If the deflecting magnetic field is due to an alternating current, the screen will show a glowing line in the form of the alternating wave, and in this manner two or more out of phase currents can be used simultaneously with the end of the electron stream describing the wave forms of these currents.

Campbell Swinton's System using Rubidium Cubes

This sort of thing can be applied to television. In Campbell Swinton's system, at the transmitting end a screen is made up of small rubidium cubes, each cube being insulated from its fellows. Behind the cubes is a chamber filled with sodium vapour which has the property of varying its resistance with the variation of illumination falling upon it. The picture of the object to be televised is projected upon the cubes so that each cube is illuminated with the varying intensity of the light and shadow of the projected picture.

Now, a stream of electrons is made to play in quick succession upon each cube, and as the electrons stream strike each cube the latter is negatively charged and discharges through the circuit. As each cube is differently illuminated by the projected picture each cube will send a current of its own through the circuit. Thus, the scanning of the picture is carried out at the transmitting end.

What happens at the Receiving End

At the receiving end these successive currents are made to influence the electron stream in an oscillograph and the electron stream is moved across the receiving screen in the same manner in which the scanning electron stream has been moving at the transmitting end. The electron stream varying in strength in the oscillograph thus rebuilds the picture on the fluorescent screen with varying intensity of glow.

It is claimed that great advances have been made with this system and, no doubt, we shall soon hear about it.

In the meantime news is scarce, as, owing to competition of the various trade interests involved, the whole thing is being kept a secret. But, while this is going on, the good old British system of television is on the ether daily, further progress is being made, and let us hope that it will outstrip all its rivals.

Those who are interested in the subject should read the following books :—

" Practical Television," by Larner (Benn Brothers).

" Television To-day and To-morrow," by Sydney A. Moseley and H. J. Barton Chapple (Pitman).

" The A.B.C. of Television," by Yates (Chapman and Hall) ; and my own modest contribution : " Seeing by Wireless," by Ralph Stranger (1s. George Newnes Ltd.).

FOUR POINTS WORTH REMEMBERING

Fig. 1.—A Combined Aerial Lead-in and Selectivity Device.

A convenient and practical lead-in arrangement is that provided by the " Wearite " stick-on variable selectivity lead-in. This consists of two metal plates, with terminals, secured by suction one on each side of the window glass. Selectivity is varied by setting the plates more or less out of register. This arrangement obviates the necessity of drilling holes through the window frame when an aerial is being installed.

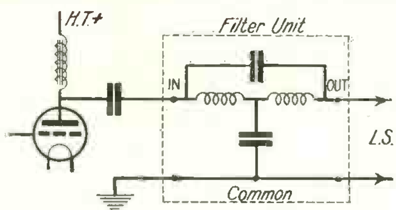


Fig. 2.—A Heterodyne Filter Circuit.

This " Wearite " filter connected in the output circuit between the output valve and loud speaker will minimise heterodyne whistles.

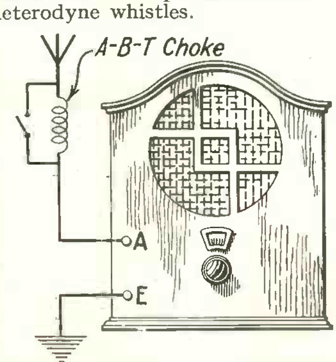


Fig. 3.—How to Prevent Interference from a Medium Wave Station when Listening to a Long-wave Station.

Showing how to connect the " Lissen " anti-break-through choke to a receiver.

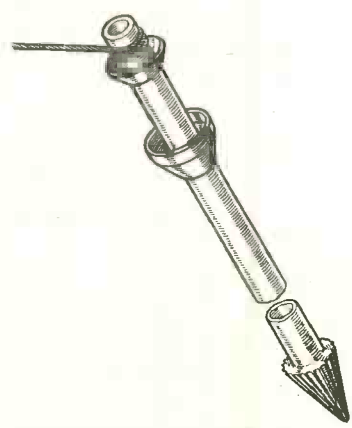


Fig. 4.—An Efficient Type of Earth Tube.

A good earth connection improves any set, and the earth tube shown here ensures a sound joint between the tube and the earth wire. It consists of a copper tube with two cups. The wire is twisted around the tube inside the top cup, and some solder placed in the cup. The lower cup is filled with methylated spirit and lighted, thus melting the solder and making a perfect joint.

METERS AND METER FAULT FINDING

By J. P. McKENZIE, A.M.I.E.E.

IN order to discover what is actually happening in practically any electrical circuit, measuring instruments are absolutely essential. For wireless purposes the following meters are used: (1) moving-iron ammeters, milliammeters or voltmeters—comprising two types which will be dealt with later; (2) moving-coil ammeters, milliammeters and voltmeters. In addition, we frequently have a combination giving volts, amperes and milliamperes on one meter, and in some testing outfits as many as nine different ranges can be obtained (see Fig. 2).

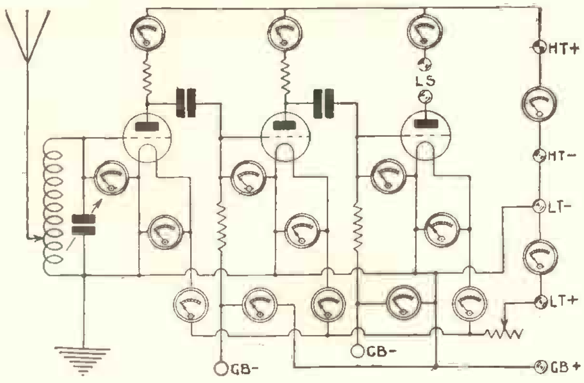


Fig. 1.—What a Three-valve Set would be like if it were Equipped with every possible Meter.

The following is a brief description of the various types of meters :—

Moving-iron Meters

There are two types, moving-iron polarised and electro-magnetic. The first consists of a pointer movement with a small specially shaped vane made from iron sheet, which is fixed to the pointer spindle forming the moving system ; the spindle which carries the pointer, balancing weight and iron vane is then mounted between two pivot screws or bearings, being free to rotate. The movement is usually mounted in a brass frame, which also has a coil of insulated copper wire wound on a small laminated iron core and fixed close to the moving-iron vane.

As the movement has no control springs, a permanent magnet is fitted in such a position that it acts on the movement and keeps the pointer on the zero mark. Current is then passed through the coil winding or meter bobbin, causing the core to become magnetised, thereby producing a strong magnetic field, repelling or attracting the iron vane on the spindle and so deflecting the pointer.

Calibrating

The calibration is made by checking against a standard meter and adjusting the coil and magnet to conform with the required reading on the dial.

Uses and Advantages of Moving-iron Meters

This meter (Fig. 3) is only suitable for measuring direct current, and can also be used as a polarity indicator.

The chief advantage of this type of meter is ease of manufacture, the absence of springs, good damping and low cost. Its uses are limited to measurements which do not require great accuracy, usually within 5 per cent.

The Electro-magnetic Type

The second type, electro-magnetic, has a movement very similar to the polarised pattern, but has a spiral spring fitted to the pointer to keep it on the zero mark.

The movement is then mounted in the centre of a bobbin of copper wire, and when a direct or alternating current is flowing, a magnetic field is set up, which rotates the movement carrying the pointer. This type of meter has the advantage of being suitable for use on A.C. and D.C., but it is not so robust as the polarised type, and damping of the movement is only provided in the more expensive models.

Fig. 2.—A Testing Outfit giving Nine Different Ranges.

Moving-coil Meters

Moving-coil meters are acknowledged to be the best type for all direct current measurements. They are more economical in current consumption, very sensitive to voltage or current fluctuations, and maintain a high degree of accuracy over long periods. Although they are more expensive than the moving-iron type, they are essential for serious radio work and especially where accurate readings are required. Reliable British-made moving-coil meters are obtainable at very reasonable prices from all reputable radio dealers, the accuracy being about 2 per cent.

Fig. 3.—A Moving-iron Meter.

Principle and Construction

The principle and construction are more complicated than in the cheaper moving-iron models and call for greater accuracy in the machining and assembly of the numerous small parts. The pointer is fixed to a small coil of wire of rectangular shape, the electrical connection being made through fine spiral springs mounted on small brass bushes fastened to the coil and fitted with a highly polished steel pivot or spindle at each end. The movement is then mounted in a frame between two jewelled pivot screws and fixed between the poles of a permanent magnet in such a way that it can rotate through a considerable arc round a cylindrical iron core concentric with the magnetic field. When current is flowing in the coil, it tends to set up a magnetic field at an angle to the field of the permanent magnet, and the reaction between the two fields causes a deflection of the pointer, which is in direct proportion to the amount of current passed.

This method of construction permits a full deflection of the pointer with a very small consumption of current, producing good damping and dead beat readings, *i.e.*, the pointer comes to rest almost immediately.

Fig. 4.—A Moving-coil Meter.

APPLICATIONS AND USES

All moving-coil meters consume a certain amount of current; a *voltmeter* is simply a milliammeter movement taking one or two milliamps to operate the moving coil, and having a high-resistance bobbin connected in series inside the case. *Ammeters* or *milliammeters* have a shunt connected across the moving coil, so that the main current passes along the shunt wire or strip, and only a fraction of current passes through the moving coil.

Voltmeters measure the difference of potential between or across a positive and negative wire in a circuit, and should always be connected in "parallel" or across any two points. The meter may be cut in or out by means of a switch connected in series or in one of the leads from any of the meter terminals.

With an *ammeter* or *milliammeter* the meter must always be connected in the positive or negative lead in "series," *i.e.*, the circuit is broken at some point and the two ends connected to the meter terminals. This will be clear from Fig. 5.

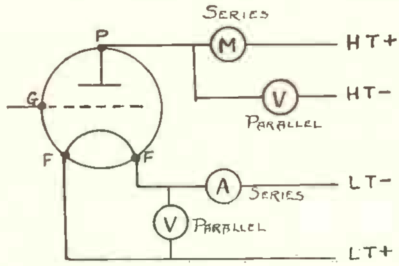


Fig. 5.—Showing how a Voltmeter should always be Connected in Parallel, and an Ammeter or Milliammeter in Series.

High-resistance Voltmeters

Voltmeters should have a high resistance, which is usually about 200 ohms per volt for ordinary radio measurements, except in cases where the meter may be used for taking voltage readings from mains eliminators, when an extra high-resistance voltmeter is essential. The resistance in this case should be at least 400 or 500 ohms per volt of the meter scale.

Why this is Important

This is a most important point when measuring the anode voltage of an A.C. mains receiver, as it greatly affects the accuracy of the reading. Actually, the higher the total resistance of the meter, the better will be the accuracy obtained. This will be clearly realised when it is remembered that the capacity or output of the eliminator is limited, being from 10 milliamperes upwards, and as the meter consumes, say, 2 milliamperes, the error in voltage reading will be at least 2 per cent. for full-scale deflection when used with an eliminator of 100 milliamperes output ; provided, however, the eliminator capacity and current consumption of the voltmeter are known, the necessary error can be taken into consideration on all readings.

Moving-coil voltmeters of reliable manufacture can be used in any circuit continuously, without fear of causing injury to the meter, but care must be taken that no overloading occurs or the insulation of the coil winding will become charred, and cause erratic or wholly inaccurate readings.

Fig. 6.—A Voltmeter having two Scales, one from 0–6 Volts and the other 0–120 Volts.

Uses of the Milliammeter

The milliammeter is the most useful instrument for locating faults and checking the quality of reproduction in radio receivers. Standard models can be obtained with scales from 2 to 1,000 milliamperes (1 ampere). Probably the most useful single-scale meter for general radio work is a meter scaled 0–30 or 50 milliamperes. Its chief uses are for measuring the individual anode current of any valve, for taking emission tests in conjunction with a voltmeter, for indicating distortion in reproduction and for tracing faults of various kinds in radio circuits.

Emission Tests

While there are universal testing sets available for taking complete emission tests of valves, this can also be done quite quickly and accurately with a suitable milliammeter and a split anode adapter, which breaks the anode lead so that the meter can be connected to two terminals, thus placing it in series with the plate of the valve and the positive H.T. tapping. To make a complete check, it is necessary to know the characteristics, which are usually supplied by the valve manufacturers on the valve carton and frequently in a separate leaflet.

It will be seen from the characteristic curve that, if a certain voltage is applied to the plate grid and filament, the anode or plate current should be x milliamps. The valve should work on the straight part of the curve and should give a steady reading. In some critical circuits, the extra resistance of the meter or the presence of the meter leads may cause instability or set up a howl, and to prevent this effect a 2-mfd. condenser should be connected across the meter terminals.

Anode Current too Low

If the milliamp reading is too low, the valve may have lost its emission, but, before replacing with a new valve, make certain by testing with a good voltmeter that the correct volts are being applied to the filament, and it is important to check direct across the valve-holder terminals.

Anode Current too High

In this case, either the grid-bias voltage is too low or there is a leaky grid connection or faulty coupling condenser; try disconnecting the grid wire from the valve holder and connect direct to the grid-bias battery, then repeat the test.

No Current Readings

This usually indicates a faulty valve or one that has lost emission through age or misuse. Before replacing, carefully check for broken or faulty connection in the valve holder and in the anode circuit back to the H.T. battery, or eliminator in the case of a mains operated set, any anode components being short circuited. Constructional faults are sometimes found in the valves themselves; a set may function normally for a certain period when switched on and then suddenly cease to operate. One of the valves is usually the source of the trouble, having a bad internal joint which just breaks contact when the valve is thoroughly heated. Leaving a milliammeter in the anode circuit of each valve in turn for some time will locate the fault.

Anode Current Fluctuating

The milliammeter should show a steady current reading when no signals are being received, and if a continual variation is shown, the trouble is usually due to the valve itself, as pointed out in the previous paragraph, or to a faulty connection in the filament, grid or anode circuit. Check the connections to the valve holder and all wiring joints, including battery connections.

Indicating Distortion

Poor quality reception in a radio receiver usually indicates that "distortion" is taking place, and a milliammeter placed in the anode circuit of the last valve will give a visual indication. If the set is working correctly, the milliammeter should show almost a steady reading, but if the pointer gives violent kicks up or down distortion is indicated, either due to excessive overloading of a valve or to faulty H.T. or G.B. batteries. Reference to the valve manufacturers' data will show if the valve is being overloaded. Check the voltage of the H.T. and G.B. batteries from the negative to each tapping with the set switched on, and as the grid-bias battery is most important, fit a new one if at all doubtful. If the milliammeter pointer kicks upwards, the valve or valves are overbiassed, and, should the pointer kick towards zero, under-biassing is indicated; adjustments should be made on the G.B. plugs until a steady reading is obtained on the milliammeter, care being taken to switch off when changing the battery tappings.

Q.P.P. Meters

The milliammeter is essential for balancing grid bias in the latest Quiescent Push-Pull circuits, and a good moving-iron type meter with a range of 10 milliamperes is quite suitable for this purpose. Valves should be balanced by inserting the meter in the centre tap transformer connection to the H.T. battery, each valve being inserted in turn until the milliamp reading is the same on both valves. If the milliammeter is permanently fitted to the set, a switch to short circuit the meter must also be fitted.

Voltmeter Tests

For battery tests a handy type of voltmeter of the portable pattern is very useful, having two scales 0–6 volts for low-tension accumulator or G.B. tests, and 0–120 volts for high-tension battery tests; always take L.T., H.T. or G.B. voltage readings while the receiver is switched on.

L.T. accumulators should never be worked below 2 volts per cell, and H.T. batteries should be renewed when the voltage has dropped below 25 per cent.; G.B. batteries require renewing when the volts have dropped 20 per cent.

Checking Voltage to Valve Filaments

The same meter can also be used for checking the voltage to valve filaments or for tracing faults in wiring, by using it in series with a small dry battery for continuity testing.

For all anode voltage tests a good moving-coil meter should be used, and for checking eliminator volts an extra high-resistance meter is necessary, with a range up to 200 volts. For convenience in testing inside the modern radio set, insulated testing prods attached to the meter leads are particularly useful.

Multi-range Meters

A test set made up in a portable case complete with resistances and shunts, so that any range of volts or milliamps can be obtained by simply changing a switch or terminal connection, is the ideal instrument for service work. The test set illustrated (see Fig. 2) has four voltage ranges, from 10 to 500 volts, and five milliamp ranges, from 2·5 milliamperes up to 1 ampere.

Universal Service Test Sets

Testing equipment for service purposes, which will enable various tests to be carried out quickly on any type of radio receiver, is now available.

Any type of valve can be checked, and by using the special valve adapter and cable supplied actual conditions in the receiver can be easily verified.

ADVANCED SPEAKER DESIGN

THE possibilities of dual speakers have attracted the attention of designers with the result that remarkable advances have been made in the technique of sound reproduction for domestic receivers.

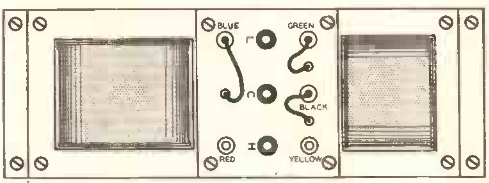


Fig. 1.—TERMINAL ARRANGEMENTS OF THE CELESTION REETONE DUAL SPEAKER.

By varying the positions of the plugs and choosing the best input combination a wide tonal choice is obtained.

The "Reetone" dual chassis S29 is a good example in this field; it has a one-piece chassis or base on which the separate cone chassis are mounted.

Connecting to Set

The input transformer has separate tappings on the primary and on the secondary windings allowing four different coupling ratios. The arrangement and marking of the terminals and sockets is illustrated; under normal conditions the arrangements given in the table will be found practical.

High Note Control

For maximum high note response, plugs in green and yellow sockets; maximum bass response, green and black; normal response, yellow and black.

Connections for Push-Pull

To use the S.29 on a push-pull set, connect terminal L to H.T.+ and connect terminals C and H to the valve anodes respectively.

D.C. currents up to 80 m.a. are safely handled by the transformer, but when in excess of 40 m.a. a choke-condenser filter assists in the quality of reproduction.

In some cases a "pentode filter" may be required.

TERMINAL CONNECTIONS TO THE CELESTION REETONE DUAL SPEAKERS

Class of Valve.	Optimum Load.	Terminal Connections.	Position of Plug.
Battery pentodes and some mains pentodes .	18,000 ohms	C and H	Red Socket
Average mains pentodes and small power valves	10,000 ohms	A and H	Blue Socket
Ordinary power and super-power valves . .	5,000 ohms	C and T	Red Socket
Large output valves	3,000 ohms	C and L	Blue Socket

RADIO DEVELOPMENT DURING THE PAST TWENTY-FIVE YEARS

By C. F. ELWELL, Fell. Inst. Rad. Eng., M.I.E.E.

Fig. 1.—AN ARC GENERATOR OF 500 K.W. INSTALLED AT CAVITE, PHILIPPINE ISLANDS.

MY professional experience of radio celebrates its twenty-fifth anniversary this year. It has been a most interesting period of my life, and it has been thought that readers of COMPLETE WIRELESS would be interested to hear at first hand of some of the developments with which I have been actively connected.

First let me say that my feeling is that had these things not been done when they were done, then somebody else would have done them and progress would have taken place just the same. Perhaps my intervention may have even retarded progress, for it might have been better, if others more efficient had done these things. But fate has willed it so, and thus with a certain amount of pride and no egotism, these notes are penned.

Early Experiments

My first paid work was in 1908, in California, in connection with some wireless telephone patents, the practicability of which was to be investigated. The first experiments were carried out over a distance of about a mile to another station, which could be seen by means of a telescope. A system of visual signals was used to report progress by my assistant. My first thrill was when one day my assistant signalled in such a way as to show that he had understood a rather forcibly expressed request on my part. Operations were then extended to three, and later to five miles, after which I made my report, which definitely discouraged any further use of the system. The difficulty was that the system made use of damped waves, and only when conditions were such that the waves were very lightly damped or completely undamped could any intelligible speech be transmitted.

Valuable Work of Amateurs

At this time, in order to spare my voice, it was my habit to use gramophone records, and the amateurs of those days used to listen to my transmissions and report progress to me, showing the helpful ways which have grown enormously with the growth of the numbers of amateurs interested in radio. The radio amateur has always been a greater factor in the development of radio than a lot of people are willing to admit. Amateurs who used to report to me on my early broadcasts are now highly paid engineers and executives responsible for valuable work in radio and its allied arts.

Conditions in 1909

By 1909 the conviction had come home to me that only by means of undamped or continuous waves would radio telephony be commercially possible, and by the use of the same means radio telegraphy would be greatly improved. At this time there was practically no use being made of continuous waves, although every effort was being made to reduce the damping of the damped waves then in use for radio telegraphy. It was thought desirable to increase the pitch of the note of the received signals in order to make them more readily distinguishable from the noises made in the head telephones by atmospheric disturbances, known generally as static. Efforts were also made to increase selectivity, which gave a certain amount of freedom from interference between stations, which by this time were beginning to increase rapidly in number.

Early Methods for Generation of Continuous Waves

The principal methods which had at that time been proposed for the generation of continuous waves of sufficient power and suitable wavelength were two in number, the Fessenden alternator and the Poulsen arc generator. Of these, the Poulsen arc appealed to me as being simpler and showing greater possibilities for rapid development in larger units. Knowing that a number of patents had been granted to Dr. Poulsen, my next step was to cable an enquiry as to whether the U.S. rights had been sold. Upon receipt of the reply my decision to go to Copenhagen was rapidly made.

Some Important Demonstrations

Upon arrival, the first demonstration which was given to me was very good radio telephony from Lyngby to Copenhagen, a distance of about ten miles. Then followed demonstrations of radio telegraphy and high-speed radio telegraphy between Esbjerg and Lyngby, a distance of 180 miles. The Poulsen arc generators used at that time were rated at 5 and 12 kw., the largest which had up to that time been built. But my conviction that the future progress of radio lay with continuous waves had been more than ever confirmed, and I was determined to obtain the U.S. rights and devote myself to developing the system commercially.

The price asked was a large one, for the inventor also realised the value of the only, until then, practical method of generating continuous waves. An option arrangement was entered into which put the formation of an American company into my hands. Two sets of apparatus were to be sent to me in California, and I had sixty days after the first successful demonstration over a distance of fifty miles in which to make a substantial cash payment, to be followed by others at rapid intervals until $450,000 had been paid.

The First Two Continuous Wave Stations

First I returned to New York and tried to obtain the necessary backing, and although some of the leading financiers in the country examined the proposition, none of them had the vision and courage to back me. But the people of California come of a more daring stock, and there the company was formed, and sufficient money advanced in order to erect the first two stations. Sacramento, the capital, and Stockton, a city 50 miles away in an air line were selected, and two masts, each 180 feet in height, were erected in each city. The aerials were known as the double-cone type, and they contained 20,000 feet of wire, as a large capacity was essential to the efficient working of the Poulsen arc generator.

The San Francisco Station

In 1910 the stations were ready, and public demonstrations were given of radio telegraphy, radio telephony and high-speed radio telegraphy. Dr. David Starr Jordan, the president of Stanford University, spoke to the Mayor of Stockton, and everything went off very well. Further funds were forthcoming, and a station was built in San Francisco with an aerial suspended from 300-feet masts. As money was not too plentiful, the wire stays consisted of used slot cable, purchased from the cable tramway company of San Francisco.

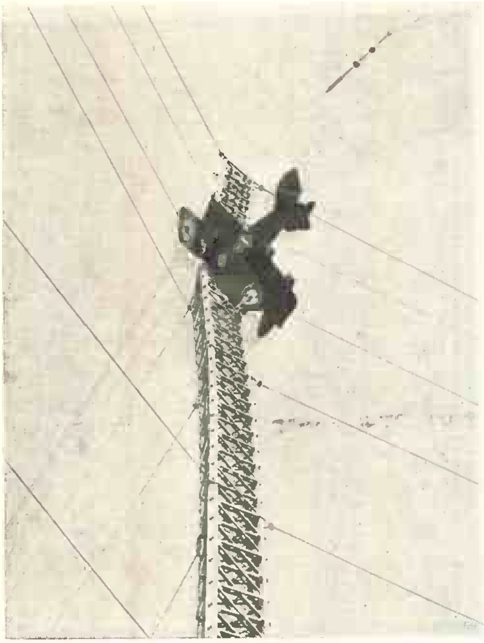


Fig. 2.—One of the Masts at the Horsea Island Station after a Heavy Hydroplane had Collided with it in a Fog.

The three stations served to show the ease with which either of the other two transmitting stations could be eliminated, and how spark interference, of which there was plenty wilfully supplied, could be dealt with. More money was forthcoming, and stations were erected in a number of large cities, forming a chain of stations from San Francisco to Chicago and Seattle. The wire-line telegraph rates were reduced by giving the public more words for the same price as was charged by the wire-line companies, and the business grew until some years later it was purchased by the Mackay interests, who still operate it.

Although results were obtained up to 300 miles with the radio telephone, it was abandoned because of the inability in those days of relaying from a subscriber's telephone line to the radio transmitter.

Communication Between San Francisco and the Sandwich Islands

In 1911 a larger station was erected in San Francisco, with two 440-feet masts and a 30-kw. generator, designed and built in our own factory at Palo Alto, and in 1912 a similar station was erected near Honolulu, in the Sandwich Islands, a distance of 2,100 miles, mostly over water. Communication by night was quickly established, and then a third mast, 606 feet in height, was erected in order to increase the power of the stations, and daylight communication was then successful. The cable rates were reduced, and a very large percentage of the available business came to our company.

How Early Radio Helped to Bring People in Closer Touch with the World

To give an idea how radio helped even in those days to bring people in closer touch with the world, it is interesting to note that the local newspaper editor told me that he had never purchased more than 120 words of the world's news daily, at the then current Press rate of 16 cents a word. We gave him a Press rate of 2 cents a word and a minimum of 1,500 words daily.

A Successful Demonstration

These results had been closely watched by the U.S. naval authorities, and an invitation to demonstrate a 30-kw. arc generator at the new high-powered 100 kw. spark station at Washington, resulted in complete defeat for the spark system and a contract to build a 100 kw. continuous wave station with three 600-feet masts on the Panama Canal zone. This was followed by high-powered stations at Sayville, Tuckerton, Pearl Harbour, Guam and Cavite, P.I., thus linking the U.S. colonies with the capital. Fig. 1 shows an arc generator of 500 kw. at Cavite, Philippine Islands.

Fig. 3.—An Early Receiving Set using de Forest "PN" Audion Detectors in Duplicate.

Why the Height of Masts was Increased

The reader will have noticed the successive increase in the height of the masts erected at each station as the distance to be covered increased. This was because it was early recognised that the amount of power radiated increased with the square of the effective height of the aerial, which, *e.g.*, made a station with 440-feet masts radiate twice as much as one with 300-feet masts, and one with 600-feet masts radiate twice as much as one with 440-feet masts. Similarly, the radiation increased with the square of the number of amperes in the aerial, and so constant development was directed to more and more amperes in the aerial, until, for thousands of miles transmissions, hundreds of amperes were in use in the aerial.

The Horsea Island C.W. Station

The foregoing development work was soon to serve its purpose, for in 1913 I came to England and interested the Admiralty in continuous waves. The Horsea Island station at Portsmouth, with three 440-feet masts and 100 kw. arc was completed in 1914, and turned over to the Admiralty just one month before war broke out. Fig. 2 shows what happened to one of these masts when a heavy hydroplane collided with it in a fog.

Sufficient experience with 14 and 24 kw. sets on board ship had been obtained to convince the authorities that continuous waves had come to stay, and that further use of the spark or damped wave systems then in use would in the future be greatly curtailed. Then followed the design and construction of many types of set, until all the principal colonies were equipped, together with hundreds of ships at sea. Continuous waves were more suitable for war purposes than damped waves.

C.W. Stations Erected in Many Countries

The French Government followed suit, and the Eiffel Tower was equipped in 1915, followed by high-powered sets at Lyons and Nantes in 1916 and 1917. When the U.S. entered the war a 1,000 kw. set was constructed at Bordeaux, in order to be able to keep in touch with headquarters in America. Ample use of smaller units was also made by the French army and navy.

Italy followed suit, and besides extensive use in the army and navy, a station was erected at Rome in 1917 in order to communicate directly with the U.S.A. This involved the design and construction of wooden masts 714 feet in height, the highest wooden structures in the world.

Only a Few Poulsen Arc Stations are Still Operating

After the war the British Post Office installed continuous-wave apparatus in the first two stations of the Imperial Chain, which had been designed before the war to use damped wave apparatus. To-day only a few of these Poulsen arc stations are operating, one of the reasons being that in the very same factory in which the first continuous wave generators were being built, a little rival generating only a small fraction of a watt was born.

Fig. 4.—The de Forest Triple Audion Amplifier (1913).

This receiver, using three "PN" audion amplifiers in cascade, gave a measured amplification of 120 times the input.

EARLY RECEIVING APPARATUS

So far, nothing has been said of the receiving apparatus required for the reception of continuous waves. The original continuous-wave detector, also invented by Poulsen, was known as the ticker. It consisted of a pair of vibrating gold wires which functioned so as to store up in a condenser the energy of a train of continuous waves and then discharged this energy into the head telephones, where the signal was heard as a low-pitched rustling note. This was later supplanted by the rotary ticker, which gave a higher-pitched note in the head telephones.

The Three-Electrode Valve

There has been a certain amount of acrimonious controversy as to who should have the credit for that modern Aladdin's lamp—the three-electrode valve. Poulsen has had the bulk of the credit for his invention, although there is no question but that it was a combination of the principles laid down by Elihu Thomson and William Duddell. Still, the fact remained that he did combine the work of the older men and thus produced a tool which did much of the world's radio transmission for about two decades.

In the same way, Dr. Lee de Forest combined the prior work of Thomas Edison and Sir Ambrose Fleming, and gave to the world the three-electrode valve, which is responsible to-day for so much of the world's radio, not to mention wire-line telephony, telegraphy, talking pictures, etc., etc. Just imagine what a peculiar place the world would be to-morrow if all the grids in all the three-electrode valves in the world failed to perform their function.

Association with de Forest

My own association with de Forest came about in the following manner. In June, 1911, he came to me and asked me to buy his Seibt wavemeter if I would care, and as wavemeters were not very plentiful in those days, I was glad to do so. Shortly after he came and asked for a position with my company, the Federal Telegraph Company, which controlled the Poulsen patents for U.S.A. It was suggested that we could best use his services on the development of the receiving side of the business, more particularly in the application of his "audion," as he called his three-electron valve, to the problems of reception. He thus came to be in charge of the research laboratory of the company.

Combination of an Audion and a Ticker

Audions were procured, and what he himself described as an intensive period of research, commenced. The first step was the combination of an "audion" and a ticker, which still further improved the note and the sensitivity. As the energy of the received signals was not in those days very large, the next improvement was amplification, using the audion as a one-stage amplifier.

Three Audions in Cascade

Then came the day in 1912 when they called me into the laboratory and showed me an arrangement of three audions in cascade. That is, the amplified output from the first stage was fed as input to the second stage, and the output of the second stage as input to the third stage. The measured amplification was 120 times the input, which far surpassed any relay then existing. This all sounds very commonplace to-day, but twenty-one years ago it was real invention, and of very far-reaching import.

One of these three-stage amplifiers was demonstrated to the Naval authorities, and also to the engineers of the Bell Telephone Company. Both recognised the value of the apparatus, and the Bell Telephone Company soon after purchased the telephone rights, and a little later the telegraph and other rights. With the huge resources in men and money at its command, the Bell Company soon had applied audion repeaters to its telephone lines and made trans-continental telephony an established commercial reality.

In fact, a few years after, in order to show what could be done, a circuit of 8,000 km. was arranged, which included some submarine cable, overhead lines, underground cable and radio telephony. To-day it is possible to telephone to some 96 per cent. of the people having telephones, no matter in what portion of the world they may be. Thus it is possible to take one's telephone in California and talk, *e.g.*, to England, Scandinavia, Java, Australia or Buenos Aires. The grouping of three "PN" audion detectors shown in Fig. 3 in cascade, making possible the three-stage amplifier shown in Fig. 4, made all this possible. And more too, if one reflects that talking pictures, wire and radio transmission of pictures and television, besides many minor applications, depend absolutely upon the three-electrode valve.

A Far-Reaching Invention

The next practical and far-reaching invention to come out of the Palo Alto laboratory was born on August 6th, 1912, according to the U.S. Supreme Court, which had the final word in settling who discovered that the three-electrode valve acted like a tiny arc generator and generated continuous waves in a suitable circuit. Of the four chief contenders for the credit, Armstrong, de Forest, Langmuir and Meissner, the credit has been given to de Forest, although, as often happens with epoch-making inventions, all four discovered the phenomenon at very closely the same time.

Paving the Way to Present-Day Developments

Once the fact was established that an audion could be employed as an oscillator, or generator of continuous waves, and with the added advantage that it did not necessarily generate a lot of harmonics as the arc did, the way to present-day developments was paved. The energy in the circuit in which the discovery was made was only a small fraction of a watt. It took a couple of years to develop the methods of manufacture of valves to the point that 20 watts could be handled by an oscillating circuit. Some of these were supplied by me to the Admiralty and French Government in the early days of the War.

The War gave a great impetus to the development of the valve, and by the end of the War the Admiralty had satisfactory 2·5 kw. valves in operation. Then came the Imperial Wireless Committee Report, which gave the arc system credit for what it had done, and predicted that the future lay with the three-electrode valve. This report so impressed me that the future lay with the valve, that I organised the Mullard Radio Valve Co. in order to be in the swim, as my old ally, the arc, was doomed to eclipse.

Modern Transmitting Valves

To-day transmitting valves of 500 kw. each unit have been constructed and put into operation. The Holweck demountable type of valve is being made in 200-kw. units, and the time may well come that valves will be constructed in units of thousands of kilowatts, if not for radio, then for long-distance electrical transmission. Thus do great oaks from little acorns grow.

What will be the Future Trend of Radio?

In conclusion, my opinion as to the future trend of radio has been asked for. This is dangerous ground but, in my opinion, there will be a strong demand for automatic volume control, or AVC, as it is called for short. The possibility of adjusting a receiving set to give the desired volume and the ability to pass round the dial without disturbing this volume, coupled with the large immunity from fading which AVC gives, will appeal strongly to listeners. There will be a demand for continued improvement in the quality of the reproduced music in preference to ability to log countless stations. The muting, either by hand or automatically, of all inter-station noises will be demanded. The Stenode principle, especially the crystal Stenode, will come into use largely on account of the absence of inter-station noises. And once adopted, the way to an increase in the number of transmitting stations, without increasing the wavelength band available, will surely follow. If this facility be translated into greater variety of programmes simultaneously transmitted, then it will no doubt be welcomed by listeners.

THE BLATTNERPHONE

SOUND RECORDING BY THE BLATTNER-STILLE SYSTEM

By T. SUTTON BRIGG

TWENTY-FIVE years or so ago a piece of apparatus known as the "magnetic detector" was largely used for the detection of wireless signals. An iron band, composed of fine, insulated iron wires, was moved slowly by clockwork through a magnetic field produced by permanent magnets. The wire was surrounded by a coil carrying the high-frequency currents to be detected, and each time a group of oscillations flowed through this coil a change in the magnetisation of the wire was produced with the result that a click occurred in a pair of telephones connected across a second coil wound over the coil carrying the oscillations. The frequency of the clicks corresponded to the frequency of the groups of oscillations, and, therefore, to the frequency of the spark at the transmitter.

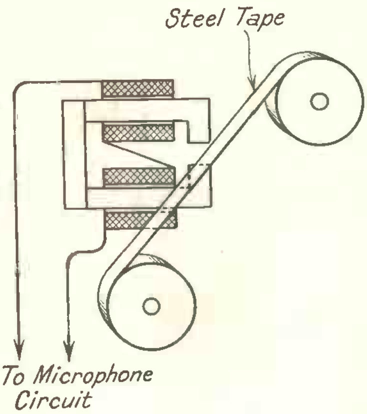


Fig. 1. — THE BLATTNERPHONE METHOD OF PERMANENT RECORDING.

Dictaphone for Recording Speech

About the same time another device employing the magnetic properties of iron on somewhat similar lines was introduced as a dictaphone for recording speech. In this case currents or speech-frequencies only were dealt with and were used to cause corresponding changes in the magnetisation of the iron, so that when the iron was passed through a coil later currents corresponding to the original speech currents would be produced in the coil.

The Blattner-Stille System

Although both of these instruments have now been superseded by others of different types, a system of recording sound which utilises the magnetic properties of iron has been developed and is now used extensively in connection with broadcasting. The system used by the B.B.C. is known as the Blattner-Stille system. A steel tape, 3 or 6 millimetres wide, of special manufacture, passes between the poles of an electromagnet as it is wound from one reel to another. The coils of the electromagnet carry the speech currents to be recorded and the steel tape is thereby magnetised correspondingly. After the recording, the tape is wound back on to the original reel and is then ready for the reproduction of the original sounds by winding it on to the second reel and allowing it to pass between the poles of an electromagnet, whose field coils are connected to a loud speaker.

The magnetised reels of tape can be kept as permanent records indefinitely, or the record can be erased by running the tape between the poles of an electromagnet whose coils carry sufficient direct current to magnetise the tape to saturation. One reel of tape is sufficient for twenty minutes' recording.

Three Sets of Electromagnets

There are actually three sets of electromagnets on the machine and they are usually referred to as the recording head, the reproducing head and the wipe-out or magnetising head. The tape is heavily magnetised by the wipe-out or magnetising head which removes all traces of previous records. The recording head carries direct current which partially demagnetises the tape so that the speech or music currents also passing through the coils of the recording head can cause corresponding changes in magnetisation. The steady direct current is of course used as a polarising current in the same way as the polarising current through a microphone.

Difficulties Experienced

Considerable research work has been necessary to bring the apparatus to its present state of high quality recording and reproduction of musical sounds as well as speech. One of the principal difficulties has been the satisfactory recording of the higher audio-frequencies.

As the frequency of the magnetising current is increased, the magnetisation is less able to follow the rapid changes in magnetising current. The nature of the tape has therefore had to be chosen with great care so that this effect is as small as possible.

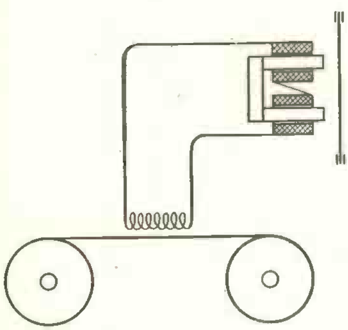


Fig. 2.—DIAGRAM ILLUSTRATING THE METHOD OF REPRODUCING SOUND BY THE BLATTNERPHONE SYSTEM.

Recording Amplifiers

The recording amplifiers used with the apparatus have also been specially designed to accentuate the upper audio frequencies to compensate as far as possible for the reduced response of the tape at these frequencies.

Background Noise

There is a limit, however, to the possible compensation in this respect, which is set by the background noise produced by the " grain " or non-uniformity of the tape similar to the needle scratch accompanying the playing of a gramophone record. This noise contains a large proportion of high audio frequencies with the result that if the apparatus is designed to record and reproduce up to these frequencies the background noise will be considerable.

Overloading

Just as a thermionic valve can be overloaded if the input is too large, so can the steel tape. The degree of magnetisation of the tape is only proportional to the input current over a limited range, consequently precautions have to be taken to keep the input within this range. The B.B.C. uses a special form of valve voltmeter for this purpose which is the same type of instrument as the one used for controlling the level of ordinary broadcast programmes. The readings on this voltmeter are proportional to the logarithm of the input, so that they more nearly represent volume of speech than would the readings on an ordinary voltmeter whose readings are directly proportional to the input.

How the Input Level is Controlled

The input level is controlled by means of a potentiometer, so that it is kept between predetermined readings on the meter which will ensure that the lowest level never falls so low that the sound will be drowned by the background hiss and will never be so great that distortion occurs owing to magnetic saturation of the steel tape.

The B.B.C. now possesses three of these machines, and they have proved so useful for programme work that one or other of them is in practically constant use throughout the day and a large part of the night. Auditions and rehearsals of plays are recorded on them and the artistes can have the record played back to them within a few minutes of its completion. In fact the only delay is that involved by the time taken to run the tape back on to its original reel, so that the record can start at the beginning and be played forwards instead of backwards. This operation takes only four or five minutes as the tape is run back at a faster speed than that used for recording or reproducing. This function of the Blattnerphone is of inestimable value in assisting producers of plays and in permitting artistes to hear their own performances as heard by the listener. These records are only of a temporary nature, and the tape is ready for immediate use again after it has passed through the wipe-out or magnetising head.

Recording of Programmes for Actual Broadcasting

Another important use of the Blattnerphone is the recording of programmes for actual broadcasting. This function has been considerably extended since the introduction of Empire Broadcasting. Items which are broadcast in the Home Programmes can be recorded on the Blattnerphone for broadcasting from the Empire Transmitters later at a time which will be convenient for listeners in distant parts of the Empire.

This method of recording sound has now reached the stage where it is possible to produce a satisfactory record on a steel tape of a previously made record. Thus portions of a number of records can be re-recorded on one single tape for special purposes, such as programmes reviewing the past year's broadcasts, without appreciable deterioration in quality. Satisfactory records have also been made on wax of Blattnerphone records.

The Blattnerphone-Stille system of recording is an excellent example of the development of an old principle, whose practical applications involved so many difficulties that other methods were found more satisfactory, to meet modern requirements, with the result that it fulfils these requirements better than do other methods which previously superseded it. Like many other useful devices, its actual method of operation is not completely understood, but research work is still proceeding and obscure points will no doubt be cleared up in time and the performance still further improved.

HOW TO MOUNT FUSES

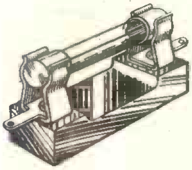


Fig. 1.—Open Baseboard Fuse Holder.

A practical type for enclosed sets. Fuses 1¼ inches in length can be used and they are held in position in clips.

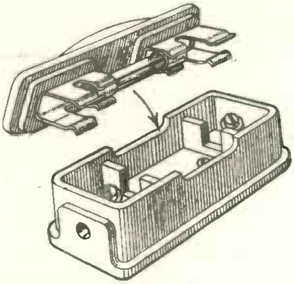


Fig. 2.—Safety Type of Fuseholder.

Removal of the lid breaks the circuit before the fuse can be touched.

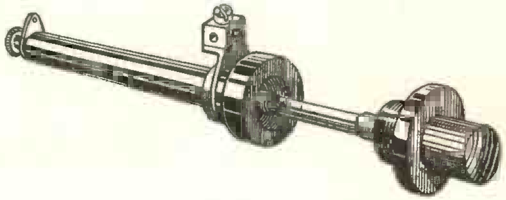


Fig. 3.—A Panel Mounting Fuse Holder.

The main feature of this type of fuse holder is accessibility without disturbing the set. To remove or replace a fuse it is only necessary to unscrew the knob at the front of the panel. The fuse is here shown partly withdrawn.

Fig. 4.—A "Flex" Fuse Holder.

This type of fuse can be fitted anywhere in a flexible lead.

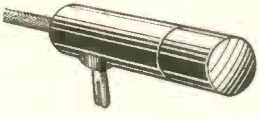


Fig. 5.—The "Wander-fuse."

A convenient type of plugging into the H.T.—socket on the H.T. battery.

Fig. 6.—The "Scru-fuse."

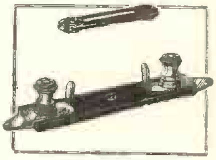


Fig. 7.—The "Microfuse."

The fuse is simply pushed on to the special holder.

HOW THE B.B.C. BROADCASTS TELEVISION

By T. SUTTON BRIGG

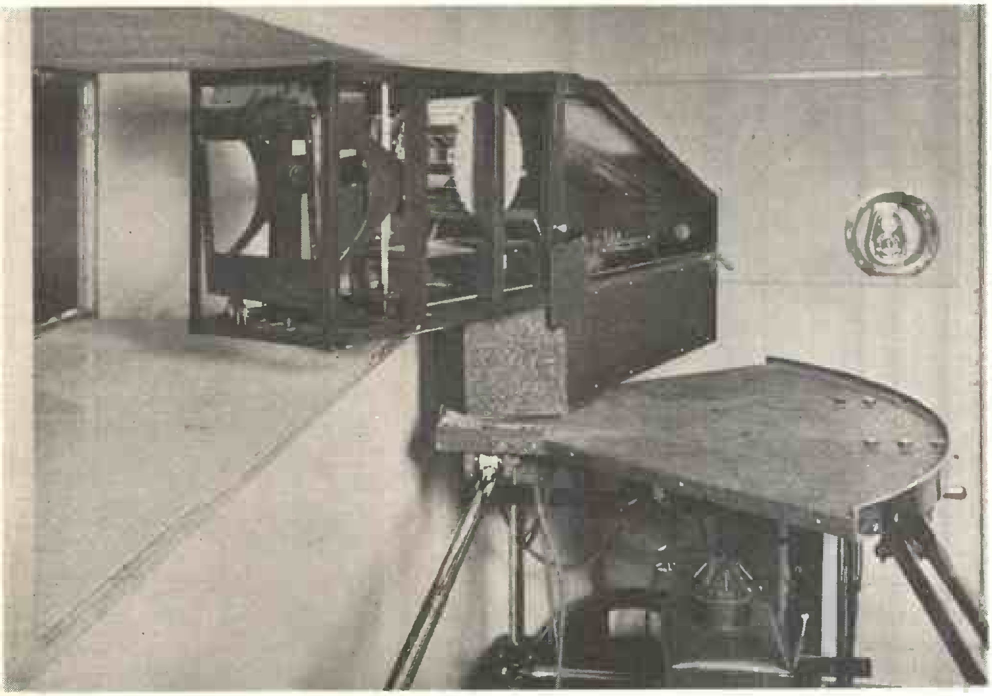


Fig. 1.—The Television Apparatus used by the British Broadcasting Corporation. The cover of the apparatus has been removed to show the inside arrangement.

ALTHOUGH experimental television transmissions were carried out by the B.B.C. as far back as 1926, it was only about the middle of 1932 that B.B.C. engineers undertook the regular transmission of television programmes by means of apparatus installed by the Baird Company in Broadcasting House. The programme side of the broadcasts has also been undertaken by the B.B.C., and it requires a special technique of its own quite distinct from the ordinary broadcasting of sound.

Studio Layout

A studio known as BB has been fitted out at Broadcasting House for these television broadcasts, and the general lay-out is shown in Fig. 2. The spotlight transmitter and the rest of the apparatus, with the exception of the photo-electric or light cells, is situated in a separate room at one end of the studio. There is a large window in the dividing wall through which the beam of light from the spotlight transmitter is projected. Two banks of photo-electric cells are situated in the studio itself as shown in the diagram, and these are connected to a mixer in the other room so that their electrical outputs can be mixed in any desired proportion in the same way as the outputs from different microphones are mixed in ordinary sound broadcasting. These electric currents from the photo-electric cells correspond to the object being televised, and after being mixed are carried to the main Control Room at Broadcasting House, where they are connected to underground cables running to the wireless transmitter at Brookmans Park, the particular transmitter used for television being the London National.

Simultaneously microphones pick up sounds in the studio and the electric currents corresponding to these sounds are also carried to the Control Room and thence to the Midland Regional transmitter at Daventry in the ordinary way.

The artist to be televised is placed in front of a large white screen at the far end of the studio for long shots, or in front of a smaller similar screen close to the communicating window for close-ups. Microphones are placed in convenient positions in the studio in the usual way for picking up sound.

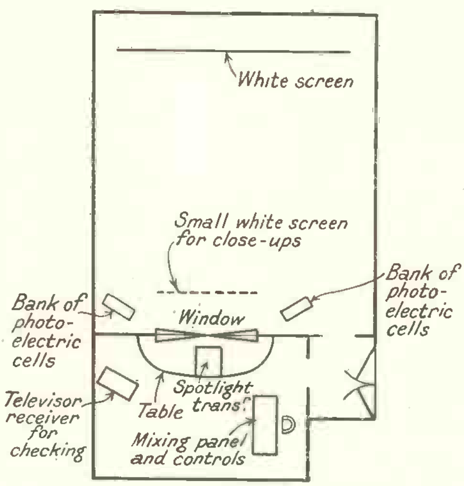


Fig. 2.—General Lay-out of the Television Studio at the B.B.C.

Spotlight Transmitter

The spotlight transmitter used for illuminating and "scanning" the artist is mounted on a special table so that it can be turned easily in order that the beam of light can be made to follow the artist moving about the studio.

The Televising Process

The actual televising pr ocess by which electric currents corresponding to the picture of the artist are produced is as shown in Fig. 3 An electric arc is used to produce a powerful source of light and the light is passed through a small square aperture close to the arc, thence through a lens on to a fixed mirror which reflects the square spot of light on to a revolving drum. This drum contains thirty mirrors on its surface, each mirror being set at a slightly different angle from that of its neighbours. The light from these mirrors is projected on to the white screen and hence on to any object in front of it. Each mirror in turn throws a spot of light which moves from the bottom of the screen to the top twelve and a half times a second and, owing to the different angles of the mirrors, immediately one spot of light has reached the top of the screen another spot from the next mirror starts at the bottom of the screen, but displaced slightly to the left. The result is to produce thirty strips of light which cover a large area of the screen, and this area is in effect "scanned" by a spot of light moving up each strip in turn.

How the Currents are Obtained which Modulate the Transmitter

At each position of the spot of light there will be reflection from the screen or any interposed artist or other object, and the amount of this reflection will depend on how light or dark the particular area covered by the spot of light is. Hence the amount of light falling on to a photo-electric cell for each position of the spot will be proportional to the whiteness of the corresponding area of the scene being televised. The variations in the intensity of the light falling on the cell cause corresponding variations in the strength of the current flowing through it, and these currents are used to modulate a wireless transmitter in the same way as microphone currents. The signals received from such a transmitter can be heard on a loud speaker, but, of course, they consist of meaningless sounds. If, however, they are passed through an instrument which changes them back into their original corresponding degrees of light then a reproduction of the scene which was televised can be obtained.

The "Televisor" Receiver

The "televisor" receiver used for this purpose requires a source of light whose intensity can be varied by the received currents corresponding to the original light variations; this fluctuating beam of light is then reflected by revolving mirrors similar to those used in the spotlight transmitter on to a small screen the various strips of which will be illuminated in the same way as the original scene which will therefore be reproduced.

How the Fluctuations in the Beam of Light are Obtained

The device used to produce the fluctuations in the beam of light consists of Nicol prisms and a Kerr cell which consists of a glass cell filled with nitro-benzene in which plates are immersed. The output of a wireless receiver is connected to these plates and causes variations in the amount of light passing through the cell which correspond to the variations in the output of the receiver. The beam of light on which these variations have been superimposed is then projected on to the revolving mirror drum, and thence on to a translucent screen which forms part of the televisor. The picture is reproduced twelve and a half times a second which is the speed at which the original scene is scanned, and owing to the persistence of vision of the human eye movements appear continuous just as in ordinary cinema pictures.

One of these television receivers is installed in the room adjacent to the studio so that the engineer who is at the controls can see if everything is all right and that he is mixing the output from the two banks of photo-electric cells correctly to get the best effect when the artistes being televised are moving about the studio.

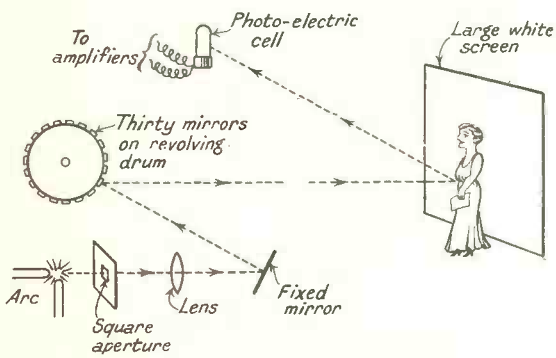


Fig. 3.—The Actual Televising by which Electric Currents corresponding to the Picture of the Artist are Produced.

Technique Necessary

The technique necessary for the satisfactory presentation of the programmes is considerably different from that required for ordinary programmes.

The artists have to wear suitable clothes and have to have their faces carefully made up to obtain the right effect. Large areas of either black or white such as, for example, a large expanse of white shirt front or a black coat which is not relieved by a white pocket handkerchief have to be avoided. For the same reason the floor of the studio is covered with black and white squares.

Changes from Close-ups to Long-shots

Sudden changes from close-ups to long-shots are now part of the regular programmes. In the close-up position a portable white screen is placed behind the artist and this is whisked away as the artist walks backwards to the large screen, to do a dance, for example. At the same time the engineer operating the spotlight transmitter moves a lever which makes the necessary alteration to the lenses for correct focus.

Black and White Pictures

The pictures which are received on the latest type of televisor are in black and white instead of being the colour of the light from the Neon lamp which was used in the earlier type of instrument. There are a number of limitations, however, which prevent a larger picture being satisfactorily obtained, and it would perhaps be as well to give a brief explanation of what these are.

The Problem of Frequency

It has already been stated that the scene to be televised is divided up into 30 strips and that each of these strips is traversed in succession by the spot of light $12\frac{1}{2}$ times a second. Now suppose that the scene to be televised consists simply of a horizontal black line on the white screen. The spot of light will cross this line $12\frac{1}{2}$ times a second in each strip, and as there are 30 strips this means that the spot of light will cross the line 30 multiplied by $12\frac{1}{2}$ or 375 times a second. Hence reductions in the amount of light picked up by the photo-electric cells will occur 375 times a second and the corresponding changes in electric current will occur at this rate. Now suppose there were 25 of these horizontal black lines, the number of impulses would now be 25 times 375, which is 9,375 per second. Thus the electric currents which have to modulate the wireless transmitter will have a frequency of 9,375 cycles per second. As a matter of fact they would contain frequencies considerably greater than this depending on the thickness of the lines, but we will not go into that here.

Frequencies too High for Transmitters to Handle

Now broadcasting transmitters are not designed to deal with modulation frequencies greater than about 10,000 cycles per second, so it is obvious that if we were to increase the number of horizontal lines that we are televising we should produce electric currents whose frequencies were too high for the transmitters to handle, and the picture which would be reproduced by the televisor receiver would not have the lines clearly defined. If, instead of our horizontal black lines, we are televising a scene which contains a lot of detail, we shall therefore require much higher frequencies than can be handled by the transmitters, and it will not be possible to reproduce all the detail. If we try to increase the size of the picture reproduced by the receiving apparatus we shall find that the lack of detail is emphasised just as any enlargement of a small photograph, which is lacking in detail, will not be satisfactory.

Similarly, it would be necessary to increase the number of vertical strips into which the scene to be televised is divided if more detail is to be obtained, and this again would increase the frequency range required. It will be obvious therefore that, before any marked increase in the size of picture can be obtained, it will be necessary to employ wireless transmitters which are capable of dealing with a considerably wider range of modulation frequencies than those now in use. Unfortunately the ether is now so congested that even if the transmitters were made to deal with the necessary frequency range they would interfere so much with each other that satisfactory reception of television would be impossible. Technical difficulties involved in designing transmitters to do this on the medium waveband are also so great as to be practically insurmountable.

Ultra Short-wave Transmitter

The B.B.C., however, is experimenting with television, using the experimental ultra-short-wave transmitter at Broadcasting House, working on a wavelength of just below 8 metres. At these low wavelengths it is a fairly simple matter to design apparatus to deal with the wide range of frequencies required for further improvements in television, and the results of these experiments should be very interesting.

MAKING A SIGNAL GENERATOR

By WELLINGS W. WHIFFIN

Fig. 1.—This Illustration shows the Appearance of the Completed Instrument.

IN principle the signal generator is very closely allied to the wavemeter employing an oscillating valve. As a rule, the wavemeter generates a tuned radio-frequency wave which is radiated directly from the apparatus and is designed to be picked up by the receiver under test when the latter is in a condition of oscillation. This system of " beating " one radio-frequency oscillator of known wavelength against a second, whose wavelength is to be determined, is known as the heterodyne or beat method of receiver calibration. It usually happens that the tuning of a receiver is slightly affected by the use of reaction and when this is increased to the point of oscillation the calibration is sometimes more seriously affected.

The Advantage of a Signal Generator over the Wavemeter

The signal generator has a more extensive application than the ordinary oscillating wavemeter. In the first place, the former has its oscillator perfectly screened so that no signal is applied to the apparatus under test except through a definite channel. The object of this is to enable the signal from the generator to be increased or attenuated at will in definite units of strength, of which the micro-volt is generally accepted as the standard. With the signal strength under complete control and at a known value, it is possible to examine and compare the merits or the amplification of different pieces of apparatus under test. Furthermore, the response of a receiver at different positions of its frequency range can be tested with a view to determining whether the ganging is correct over the whole tuning range. In the band-pass receiver, some interesting experiments can be carried out to check the efficiency of the various forms of filters.

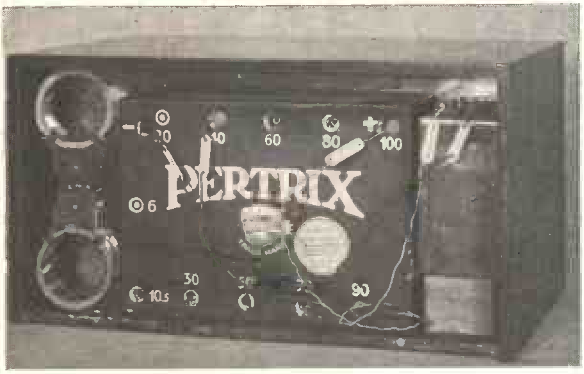


Fig. 2.—Showing how the Batteries and Spare Coils are Housed at the Back.

The Modulated Output of the Generator

It would be impossible to carry out the foregoing tests if one were to rely upon the condition of oscillation in the receiver under test.

In place of this, the radio-frequency output of the generator is modulated with an audible note of the same character as the tuning note of the broadcasting stations. By this means, the instrument may be used in circuits which are not in oscillation, such as a receiver tuned for normal reception. It will be seen that, by this arrangement, a set can be calibrated under its proper working conditions. In expensive laboratory generators, the extent to which the carrier or radio-frequency wave is modulated can be varied, the output of a separate valve designed to oscillate at an audible frequency being mixed with the carrier wave output.

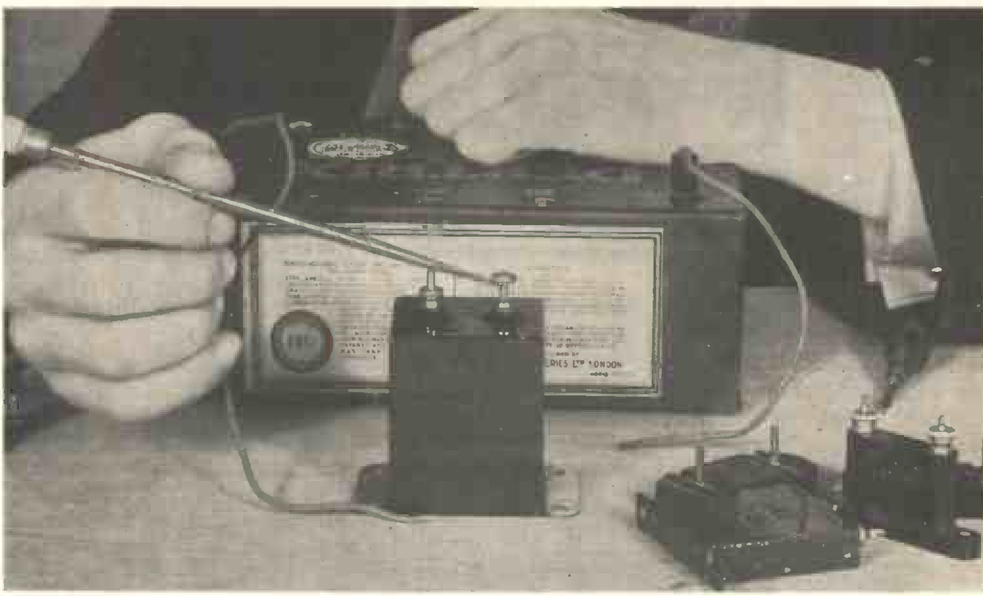


Fig. 3.—To Safeguard the Meter, the Blocking Condenser must be Tested for Leakage.

General Description of the Signal Generator to be Constructed

A Mazda, S.G.215 screened-grid H.F. valve supplies both the carrier-wave and its audio-frequency component by arranging electrode voltages so that the "negative resistance" portions of the characteristic curve are utilised. Used in this way, the outer screen is at higher potential than the anode, while the control grid is connected directly to the positive side of the filament heating battery. No method of feed-back is required, such as capacitative or magnetic coupling between grid and anode, to bring about a condition of sustained oscillation. The theoretical circuit to which the generator is wired is given in Fig. 4. It consists essentially of two distinct sections, the oscillator, which is a complete unit in itself, and an alternating current voltmeter with suitable resistances for measuring the strength of the signal from the generator after it has been rectified and amplified by the receiver under test.

The Special Attenuator

In designing the signal generator some consideration was given to the method of varying the signal output in definite steps. The principle of a pick-up coil capable of variable coupling to the tuned coil was rejected on account of the possibility of upsetting the calibration when closely coupled. Finally, it was decided to insert a resistance in the oscillating circuit and to take advantage of the potential drop across different portions of it. This scheme was found very satisfactory as the output required was so small that the low value of resistance necessary had no effect upon the operation of the circuit. Furthermore, the load due to the resistance being practically constant, no change in working conditions was to be expected from this source. As the voltage drop is directly proportional to the amount of resistance included in the output circuit (ignoring the external load) it is an easy matter to calibrate the attenuator in progressive steps. A small fixed condenser and a series resistance are connected from the attenuator to an alternative output terminal, their object being to provide the constants of the average aerial system. For this reason the circuit is known as a "dummy" aerial.

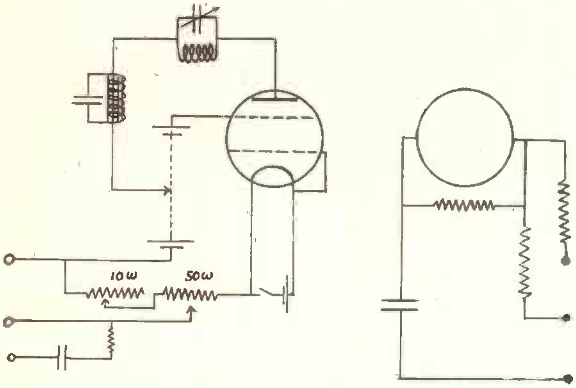


Fig. 4.—The Theoretical Circuit of the Generator and the Meter Circuit.

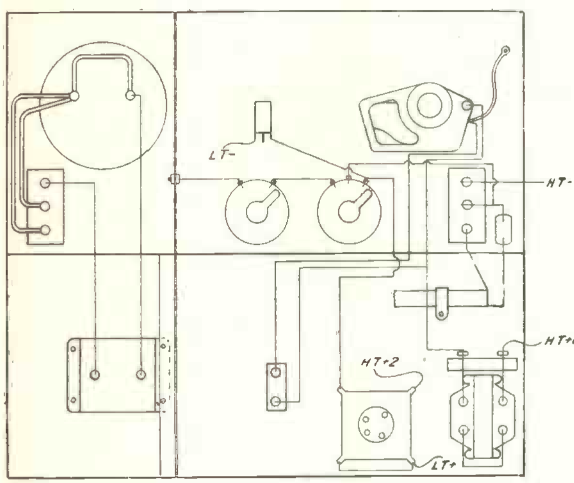


Fig. 5.—Lay-out and Wiring Diagram.

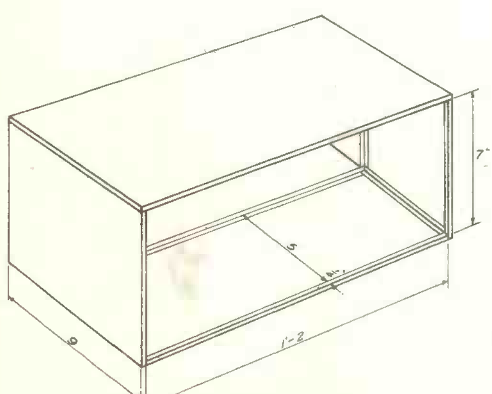


Fig. 6.—The Dimensioned Drawing of the Cabinet.

The Tuning Arrangements

The radio-frequency circuit is tuned with a "Polar" Ideal variable condenser with vernier adjustment. Its maximum capacity is ·0003 mfd., this value being chosen as a larger capacity renders accurate calibration more difficult, and by the reduction of the inductance to capacity ratio tends to prevent the circuit from oscillating at higher wavelengths.

Partly for this reason, plug-in coils of the Igranic honeycomb type are used in order that the effective wavelength range may be extended to cover all broadcast wavelengths. The use of plug-in coils also enables the signal generator to be employed in testing and calibrating short-wave receivers and the intermediate-frequency circuits of the superheterodyne.

Choosing the Components

A number of tests have been made to determine the suitability of different com-

Fig. 7.—Fitting the Internal Shields to the Cabinet.

loading to which it will probably be subjected. The meter is of the flush-mounting type obtainable in 2½ or 3½ inches diameter face. The larger size is illustrated. The safety of the meter depends largely upon the reliability of the 4 mfd. block condenser, which prevents the flow of direct current through the meter circuit when testing the output of a receiver. The condenser illustrated is a T.C.C. Mansbridge type of 500 volt D.C. test.

ponents to those actually used and photographed in the generator constructed. It was found that any well-made component gave good results, which justifies the constructor in selecting material from any stock which he may have in hand. It is not advisable, however, to change the variable condenser unless the alternative is known to have a good power factor. The output meter, an Everett Edgcumbe 0–1·5 A.C. voltmeter of dwarf type RML, has been specially chosen on account of its ability to stand the hard usage and over-

Checking the Blocking Condenser

The "goodness" of this blocking condenser is checked in the manner shown in Fig. 3. The condenser is charged by applying two leads from a high-tension battery to the terminals or soldering tags at the top of the block. A screwdriver is then momentarily joined to the terminals to produce a sharp spark during its discharge. If the condenser is a good one, this quick discharge should build up a potential across the contacts of opposite polarity, showing a smaller spark discharge on shorting with the screwdriver for a second time. A further test is to charge the condenser as before and to leave it for several hours before discharging

Fig. 8.—French Polishing the Cabinet. Note the Hole in the Corner for the Battery Cords.

it. Again, a spark should occur to show that the charge has been held during the period of conservation. The illustration shows some smaller condensers which were tested for leakage and destined for use in determining the pitch of the modulation frequency.

Proceeding with the Construction

The simple box-like form of the cabinet is shown in Figs. 1 and 2, illustrating the front and back views of the signal generator when completed. The back of the cabinet, removed to show how the high- and low-tension batteries and the spare tuning coils are arranged, is a piece of ply-wood screwed in position to a fillet of wood at the top of the cabinet, and to the back edge of the cabinet base at the bottom. A dimensioned sketch of the cabinet is given in Fig. 6. It should be solidly constructed in hard wood to withstand the weight of the batteries. The front part of the cabinet, devoted to the generator itself, is well screened with an aluminium lining of 24 gauge sheet. Two flat pieces measuring 14 inches long and 5 inches wide are screwed to the top and bottom, and two smaller pieces, 6¾ inches high and 5 inches wide, shield the sides. The front edges of the aluminium should be $\frac{3}{16}$th inch back from the front edges of the cabinet. The shields are secured in position by strips of ½ by ½ inch angle aluminium screwed at each of the four inside corners. These angle pieces assist materially in strengthening the cabinet as well as perfecting the nature of the screening. As the two side strips at the base form runners in sliding the chassis in and out of the cabinet, it is important that countersunk screws be used.

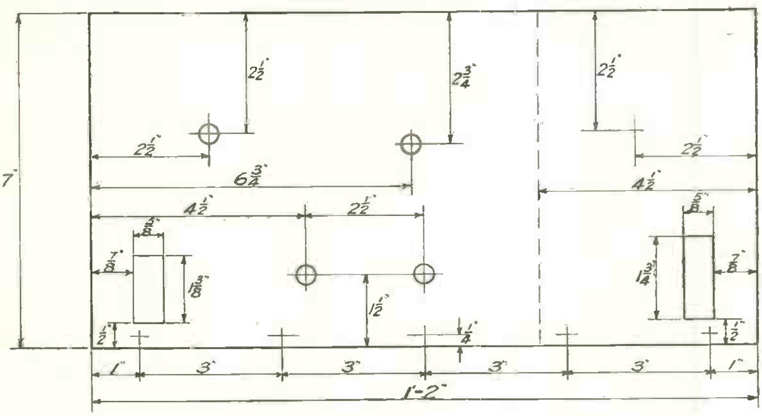


Fig. 9.—Dimensioned Drawing of the Panel Lay-out.

The Screening

The general form of the screening is shown in Fig. 7, where similar angle strip is screwed all round flush with the back edges of the shields. It is necessary to cut away small pieces at the ends so that the strips may fit in with the four side strips already secured.

The Back Partition

The back partition measuring 14 inches long and 7 inches wide is cut from the same gauge aluminium. Before bolting it to the angle pieces a corner is cut off to leave a hole about ½ inch square at the bottom left hand corner when the cabinet is viewed from the front or shielded side. This hole permits the battery cords to pass through to the battery compartment, and is clearly ilustrated in Fig. 8. This illustration also shows the operation of French polishing the cabinet, a process which follows the completion of the internal screening.

Preparing the Panel

The panel is cut in No. 20 gauge sheet aluminium to measure 14 inches long and 7 inches deep. Dimensioned positions for the components supported on the panel are shown in Fig. 9. The method of insulating the various terminals from the panel should be noted. One of the three signal output terminals is to be earthed to the panel and will form a means of bolting the latter in position, the remaining two being centrally placed in the oblong hole cut to receive them. The three terminals for connection to the meter circuit must be well insulated. Two plates of paxolin are cut to measure 2 inches by 1 inch, holes for the two outer terminals being drilled centrally $\frac{5}{8}$th inch from the centre hole. Both plates are drilled together so that the holes will correspond. One plate is fitted to the front of the panel and one to the back, tightening the terminal nuts when the panel is fitted exactly over the oblong hole (see Fig. 10).

The Baseboard

The baseboard measures $13\frac{5}{8}$ inches long and 5 inches wide, cut from 4-ply wood of $\frac{1}{4}$ inch thickness. Countersunk woodscrews secure it to the panel, $\frac{1}{16}$th of which is allowed to project on the underside of the baseboard.

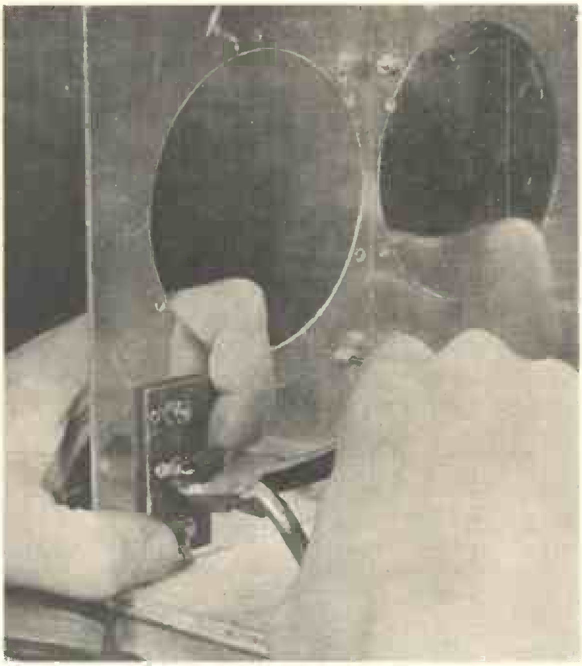


Fig. 10.—Illustrates how the Terminals are Insulated from the Metal Panel.

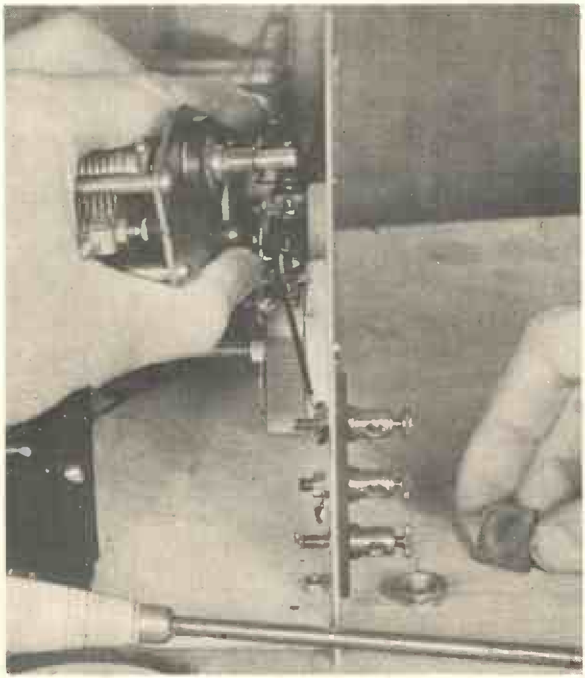


Fig. 11.—The Variable Condenser is Clamped to the Panel between Insulating Washers.

Take care in drilling and screwing the baseboard, when fixing the panel, to avoid splitting open the various sections of the plywood. The rigidity of the panel to the baseboard is assured by an aluminium partition, $6\frac{3}{8}$ inches high and $4\frac{7}{8}$ inches wide screwed in position as shown by the dotted line in Fig. 9, with two strips of the angle aluminium used in screening the cabinet.

Mounting the Components

The variable condenser must be well insulated from the panel by ebonite washers placed on either side of the panel and over the condenser fixing bush. Either washer should be "stepped" in order to locate the fixing bush centrally in the fixing hole. These washers are shown in Fig. 11, in which the condenser is seen being mounted in place. The

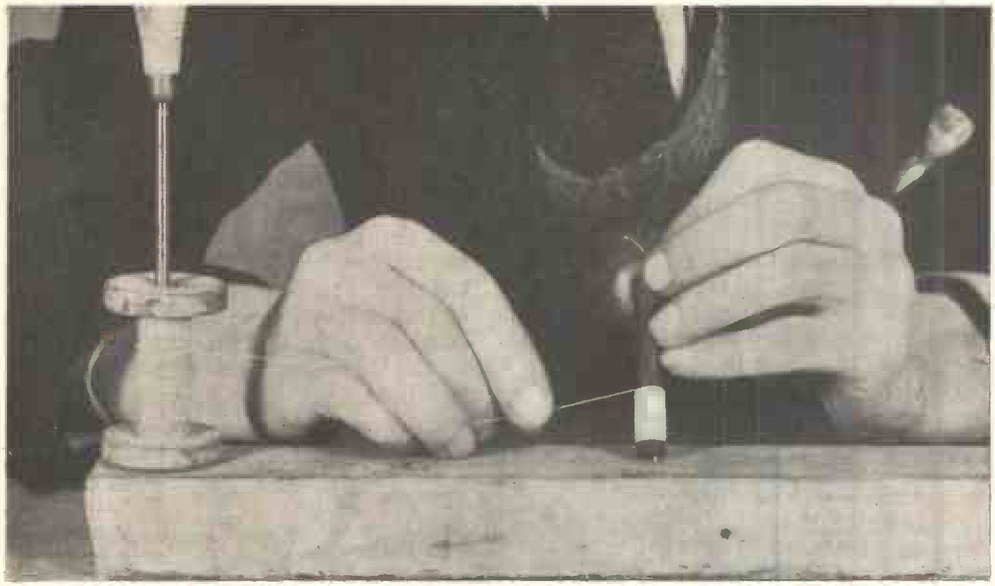


Fig. 12.—WINDING THE RESISTANCE FOR THE DUMMY AERIAL.

theoretical circuit diagram shows that the attenuator consists of two variable resistances, one of which is used as a potentiometer. This control of 50 ohms forms the coarse adjustment and is placed nearer to the variable condenser. The second, of ten ohms, is a variable resistance and is bolted in position to the right of the first.

The Igranic porcelain base resistances shown in the illustrations have the advantage of dispensing with any bushing, which will be necessary if centre fixing hole resistances are employed. It is important to see that the control spindles have ample clearance through the panel holes. As the low-tension battery switch is bolted directly to the panel care must be taken to see that the body of the switch is insulated from the contacts. If a miniature mains switch is obtained there need be no fear of a short-circuit to the panel from this cause.

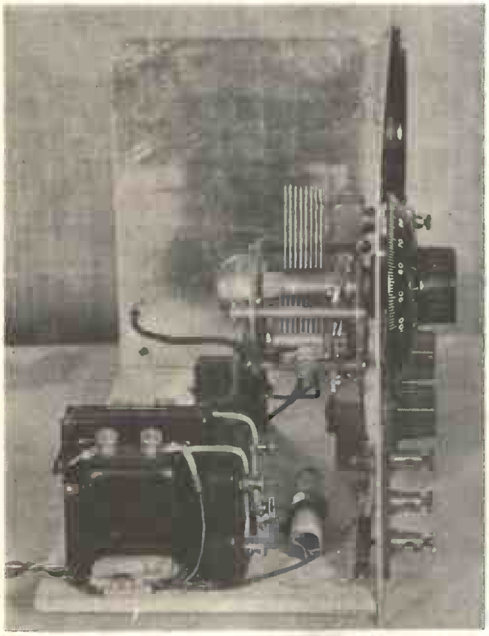


Fig. 13.—A SIDE ELEVATION OF THE GENERATOR SHOWING HOW THE DUMMY AERIAL RESISTANCE IS FIXED.

Making the Dummy Aerial

For the resistance part of the dummy aerial, a 2½-inch length of ½-inch diameter ebonite rod or tube will be required. Drill two very small holes to anchor the beginning and end of the wire. The value of the resistance is about 300 ohms, which is obtained by winding two layers of No. 38 S.W.G. Eureka resistance wire across the tube, leaving a space of ¼ inch at each end. A convenient method of winding is shown in Fig. 12, where the tube is kept in position over a nail driven into a block of wood. The reel of wire is similarly held with a screwdriver. The tension can be regulated by allowing the wire to pass through the fingers of one hand while those of the other hand impart a rotary motion to the tube. It will be found that about 150 turns will fill the allotted space on each layer. The method of clamping the tube to the base-board is illustrated in Fig. 13 showing a side view of the generator with the wiring completed. One end of the dummy aerial resistance is soldered to the bottom of the three signal output terminals and the other to one side of a small fixed condenser of ·0001 mfd. capacity, whose second contact is bolted under the centre terminal. This terminal also connects to the centre and moving contact of the 50 ohm resistance.

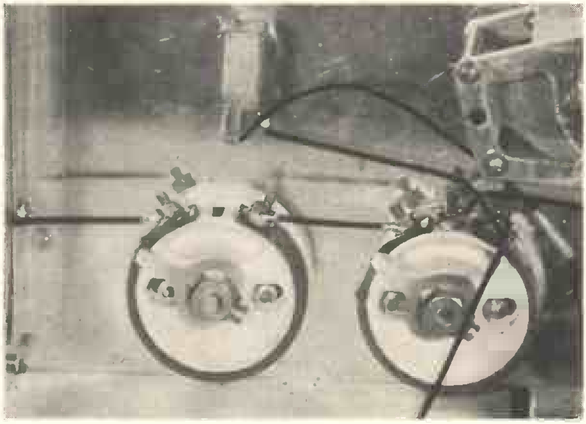


Fig. 14.—A Close-up View of the Attenuator Wiring.

Wiring the Attenuator

An enlarged view of the wiring of the attenuator is given in Fig. 10. Unless this is closely followed, the constructor may find that the process of attenuation of signals is obtained by turning the controls in opposing directions.

Two views of the completed wiring are given in Figs. 15 and 16, the plan view showing a long-wave coil and the valve in position. The side elevation illustrates the method of wiring the resistances in the meter circuit. The resistance of 1,000 ohms is wired across the meter while the two resistances of higher value connect to two terminals on the meter terminal panel and one terminal on the meter. If the latter has a "plus" sign on one terminal, this should be ignored. Note that the blocking condenser is held on one side by slipping its fixing strip under the bottom of the central partition.

Determining the Pitch of the Audible Note

The frequency of the modulated note will depend upon the actual L.F. transformer employed and the value of the capacity shunted across it. A number of transformers were tested, and all were successful. In determining the pitch to be used, it must be remembered that no less than four different values of inductance are obtainable by using the primary or secondary windings only or by wiring both coils in series to give an additive or opposing effect. A transformer can be used in which one winding has been burnt out and is therefore unfit for normal service. The value of the shunted condenser to tune the audio side of the oscillator will lie between ·01 and ·1 mfd. Connect the generator to batteries and the signal output to the aerial and earth terminals of a receiver. A number of condensers can be connected across the transformer, either collectively or individually until a suitable note is obtained. If a high-tension battery of 100 volts is employed to obtain full screen voltage, then the anode voltage should be about 30 to 50 per cent. of this value. It will be found that the actual anode voltage has an important bearing upon the loudness of signals.

Completing the Construction

We have now dealt with all the main points concerning the construction of the signal generator, and the final details

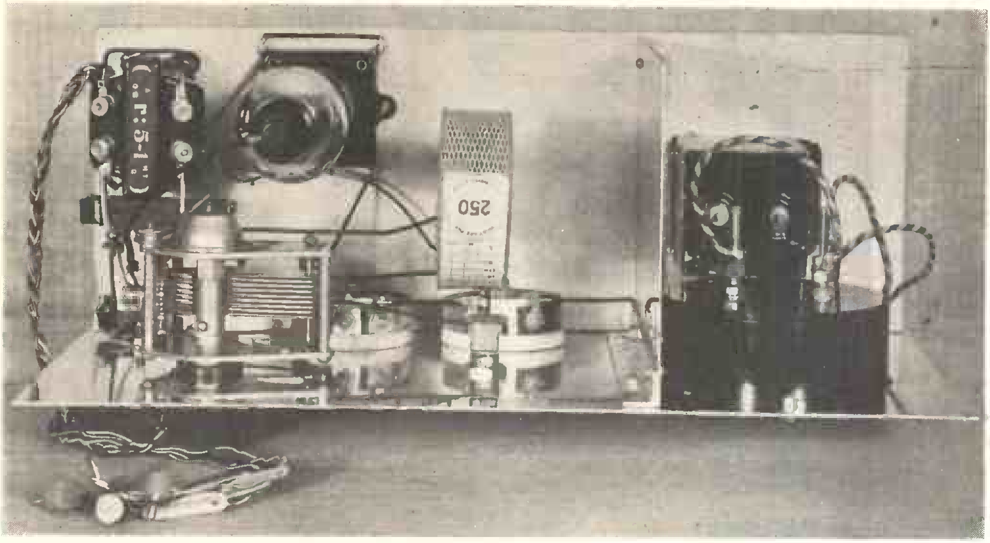


Fig. 15.—A Plan View with the Valve and Long-Wave Coil Fitted.

concerning the operation and the many uses to which the instrument can be applied, can now be dealt with. The actual construction is completed by smearing the attenuator resistances with vaseline to ensure noiseless operation as shown in Fig. 17, after which the finished work is slipped into its cabinet with the battery cords extending through the hole cut for this purpose (see Fig. 18). To make sure that good electrical contact exists between the panel and the internal shielding, a short length of flexible insulated wire is connected to both metallic parts.

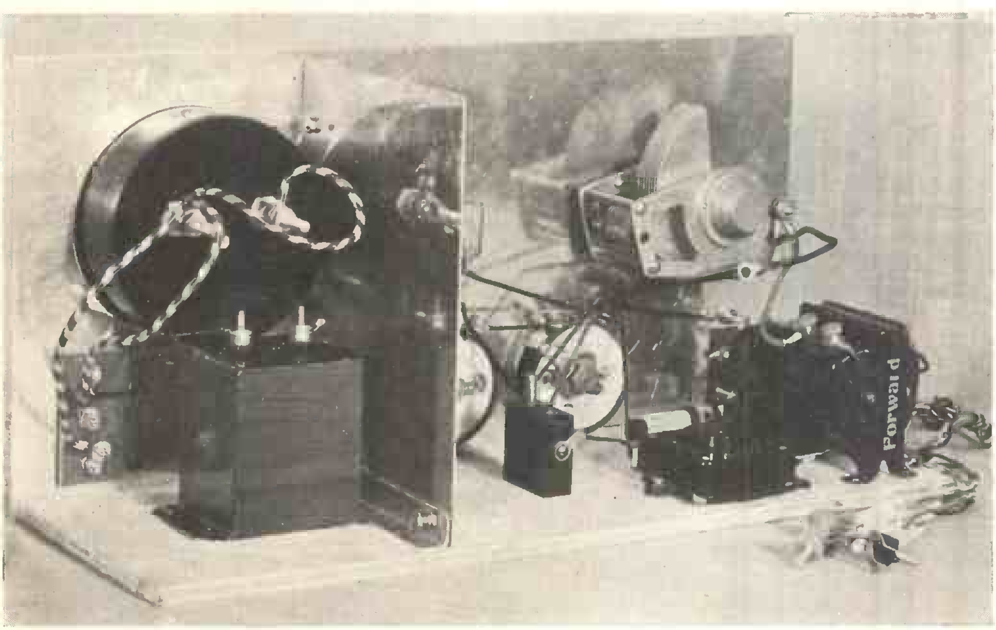


Fig. 16.—Spaghetti Resistances Form the Major Part of the Meter Wiring.

OPERATING THE SIGNAL GENERATOR

Tests

So much for the constructional side. We will now deal with the use of the signal generator. It may be as well to describe the steps to be taken before it is possible to apply it for testing purposes. Check carefully the wiring of the components to the drawing of the panel and lay-out given on p. 1429. This is stressed as a slight modification to the wiring has been made to improve the generator since the photographs were taken. With the battery cords suitably labelled with ivorine tags, the wander plugs of the high-tension battery and the spade terminals of the two-volt accumulator are properly connected. Ignoring the meter terminals for the time being, connect the two top terminals of the generator output to the aerial and earth terminals of a receiver. In order to avoid a mistake in connections, the terminal board should be marked in descending order of terminals, " Earth," " Direct Output," and " Dummy Aerial."

Fig. 17.—The Vaseline on the Attenuator will Ensure Smooth and Silent Operation.

Tune the receiver to a wavelength of roughly 400 metres and plug in an Igranic coil No. 50, or its equivalent in any other make. The generator need not be enclosed in its cabinet at the moment. Rotate the variable condenser of the latter when the receiver is tuned to its maximum output. If the audio side of the generator is working correctly, an audible hum should be heard in the loud speaker when the wavelengths of both instruments are in tune. If this note is absent, it is probable that the L.F. oscillations are not within audible range. Check the H.F. oscillations of the generator, as a preliminary step, by repeating the above test with the receiver in an oscillating condition. Now, the loud speaker should emit two sharp whistles as the variable condenser of the generator is turned past the point of resonance of the two circuits. Turn the attenuator controls clockwise to obtain maximum output if the whistles are faintly heard. If the whistles are still absent, check over the generator voltages and connections.

The Correct Anode Voltage

It has been mentioned that the voltage applied to the anode of the S.G. valve has an important influence on the satisfactory oscillation of the valve. Broadly speaking, this anode voltage should be half the value of that applied to the outer screen. Vary the anode voltage between 30 and 60 volts with a maximum of 120 volts on the outer screen.

Choosing a Suitable Valve and Coil

It has been found that some valves oscillate more readily than others, so that if another valve is available it should be tried. It is interesting to note that once a valve has been operating on a higher voltage, it shows a strong disinclination to work again at a lower voltage. For this reason, the valve selected should be a new one or one which has not been overrun. If difficulty is found in getting the generator to oscillate at radio-frequency,

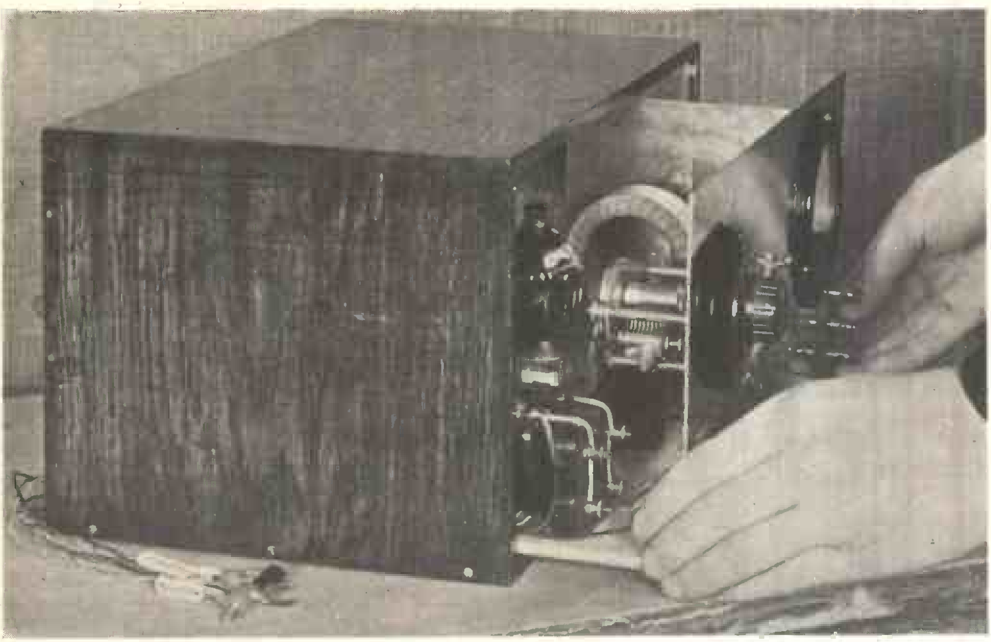


Fig. 18.—Sliding the Finished Instrument into the Cabinet.

change the tuning coil for another make or clean the contacts to minimise H.F. resistance.

Obtaining the Correct Audio Note

Assuming the H.F. oscillations to be satisfactory, decrease the reaction control of the receiver until only the valve hiss of the oscillator is faintly heard. The value of the L.F. modulating note is found by adding or subtracting condensers in the manner previously described. The higher the total capacity shunted across the L.F. transformer the lower will be the resulting note. On no account should a gruff unsteady note be chosen.

Overloading

Under the conditions in which the tests outlined have been made, there is strong probability that the receiver is now very much overloaded as the output of the generator is brought to perfection. Do not, therefore, decide upon the suitability of the audible note until adjustments in volume have been made. Overloading can be detected by the presence of two tuning points or " humps," one on either side of the correct position indicating resonance. An audible note of 400 cycles is suitable.

The Attenuator

As the signal generator is not fitted into the shielded cabinet there will be direct pick-up to the receiver in addition to the signal properly applied through the output leads to the aerial and earth terminals This pick-up can be demonstrated by removing the connecting leads from the generator. As the latter is pushed into the cabinet, the pick-up will gradually disappear. It should become inaudible when the shielding is complete and the output leads are removed from their terminals. Further progress should be retarded until all symptoms of direct pick-up have been eliminated. On no account must the signal generator batteries supply the current for operating the receiver under test if the signal output is to be under complete control. The generator will work successfully with an A.C. mains eliminator, but coupling must be expected if an A.C. mains receiver is under test.

With any pick-up trouble cured, the connecting leads to the receiver are replaced and the signal again tuned in on the loud speaker. There should be a cessation of signal output when the attenuator controls are turned to minimum. If the note persists, it indicates the presence of resistance between H.T.— and L.T.—. Examine the resistances of the attenuator to make certain that all resistance is cut out in the position of zero signals.

Calibrating the Attenuator

Unless a micro-voltmeter is permanently wired across the output terminals, it is not possible to calibrate the attenuator directly in terms of fractional volts. This is because the output at different frequencies is not constant. Except for sensitivity tests, where a standard of output is required, no need will be felt for actual voltage calibration. All that is required is two similar dials divided plainly into equal divisions so that the ratio of signal increase is observable. The complete rotation of the 10 ohm resistance will give $\frac{1}{5}$th of the total voltage developed across the second resistance.

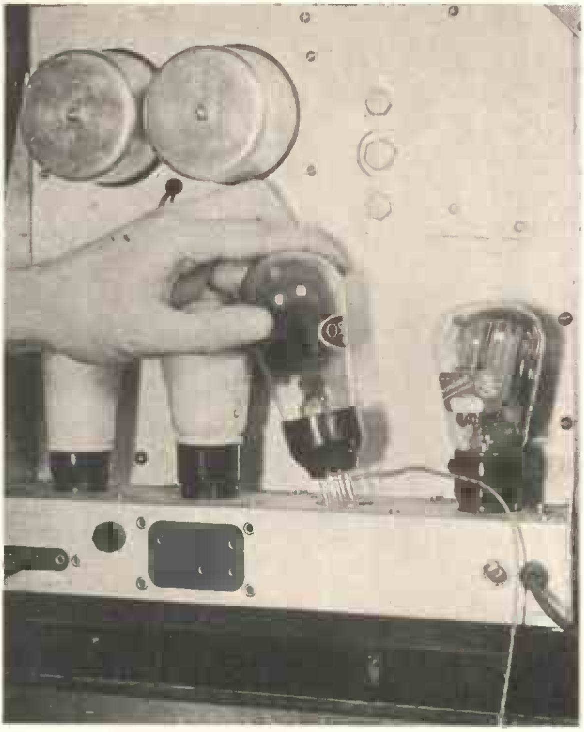


Fig. 19.—Showing how Connection is Made to the Anode of the Output Valve.

On p. 588 is described a valve voltmeter which will be of very great assistance to the experimenter who wishes to work with a knowledge of voltage output. As its input resistance is extremely high compared with the signal generator output resistance, the former can be shunted across the output terminals to obtain voltage readings.

How to Match Coils

A concise description on matching coils is given in the article entitled "How to make a Valve Voltmeter," which has been mentioned before. It will be found of very great advantage to substitute the output from the signal generator instead of using the local transmission in checking the efficiency of coils. The dummy aerial and earth terminals are used instead of employing the broadcast transmission.

Using the Meter

The meter has been included in the signal generator to provide a visual indication of the state of resonance between the generator and the receiver under test. It is not so satisfactory to rely upon the ear, which cannot detect readily the optimum tuning point. The meter is to be shunted across the last valve from anode to filament or cathode, or in some other manner to form an alternative path to the loud-speaker currents. The flow of direct current is prevented by the 4 mfd. blocking condenser, and restricted by either of the high value resistances which connect two output terminals to the meter.

Making Connection from the Output Valve

A quick method of making connection from the output valve of a commercial receiver is shown in Fig. 19, which is a view of the back of a Kolster-Brandes 3-valve

All-Electric receiver. The illustration shows a flexible lead twisted securely round the anode pin of the output valve. This wire is firmly held when the valve is returned to its holder. Care must be taken that the wire does not short-circuit to the chassis.

It is a good plan to mark the three meter terminals, such as "High Resistance," "Low Resistance," and "Common." The first mentioned should be used on all preliminary tests. The second output lead connects the other meter terminal to the receiver chassis. As a protection to the meter, the attenuator should not be turned to maximum until the readings justify it.

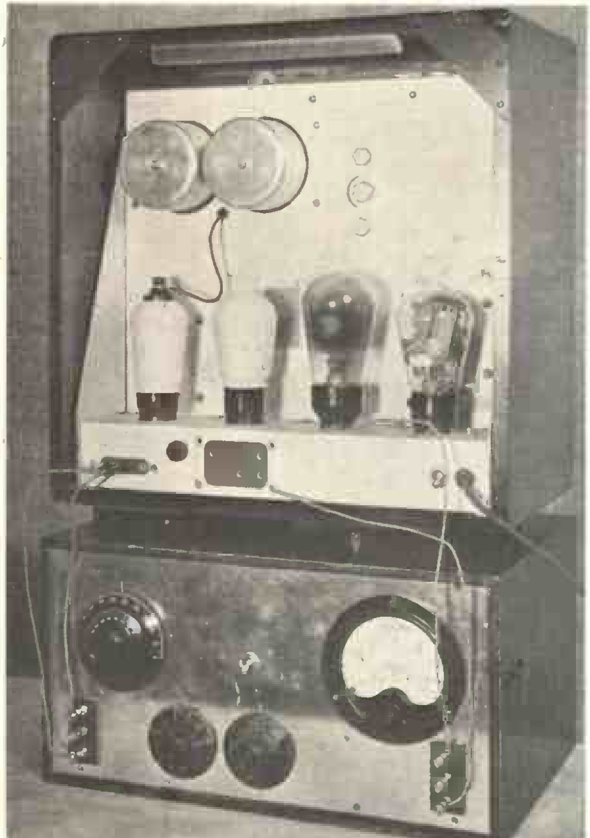


Fig. 20.—Showing how to Connect the Generator to a Receiver Under Test.

The Wavelength Calibration

To calibrate the generator in wavelengths, or in terms of frequency, it is necessary to plot a curve of wavelength readings against the scale settings of its tuning condenser. Tune in carefully a known transmission on the receiver. With a suitable plug-in coil in the generator, remove the aerial and earth from the set and substitute two leads from the dummy aerial and the earth terminal. The meter may be connected as outlined to ensure the greatest accuracy in reading. Without disturbing the receiver in any way, rotate the generator wavelength control until the latter is tuned exactly to the receiver. Adjust the attenuator to avoid a false reading through overloading.

Thus we now have one point on the generator scale in tune with a known transmission. A number of points are plotted in the same way and linked up to form the complete graph. It is important not to confuse the readings by picking on an harmonic in mistake for the fundamental note.

Comparative Tests for Receiver Selectivity

Connect the dummy aerial and the meter terminals to a receiver input and output as was used in the calibration of wavelength. The method is shown in Fig. 20, in which the receiver under test is connected ready for use. It is tuned carefully to the signal from the generator at the wavelength chosen. The attenuator is adjusted so that the output meter gives a definite reading of, say, ·9 volt. The scale setting of the receiver is accurately noted and the latter detuned. The attenuator value is increased approaching its maximum, the increase from its original level being recorded. Again tune the receiver slowly until the meter reading is restored to its old value.

As the input to the receiver is now much greater than before by a known amount, the new scale setting will differ from that already obtained. A similar reading must now be taken on the opposite side of the tuning peak. Rotate the receiver wavelength control very rapidly past the peak in order that the excessive signal now applied shall not damage the meter. Note the second reading at which the meter indicates the same output. As a result of these experiments the actual spread of the signal can be determined for a certain increase in signal strength. By applying this test to a number of other receivers, a very good idea is obtained of their selectivity performance under conditions of reception. The principle of this test is shown in Fig. 21. The bottom peak represents the original signal giving ·9 volt output while the centre one shows the increased signal on a selective receiver. The outer peak is likely to be obtained on a set possessing flat tuning, the spread of signal being excessive.

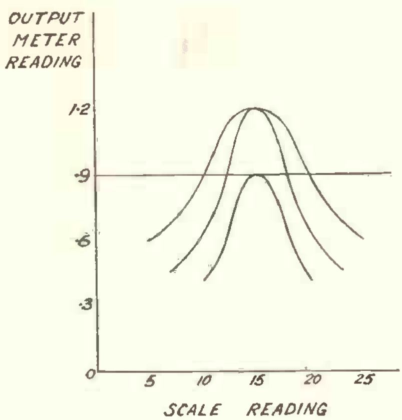


Fig. 21.—THE PRINCIPLE OF THE TEST FOR THE ACTUAL SPREAD OF THE SIGNAL.

The bottom peak represents the original signal giving ·9 volt output, while the centre one shows the increased signal on a selective receiver. The outer peak is likely to be obtained on a set possessing flat tuning.

Ganging a Receiver

The process of ganging a receiver has been described in these pages, and with the signal generator connected exactly as used in the experiment described above, the perfectly constant nature of the note, the facility of visual reading, coupled with the ability to vary both the frequency and the strength of the signal will be found of the greatest advantage in ganging circuits to resonance.

Determination of Second Channel

Second channel interference is peculiar to superheterodyne sets and is manifested by a continuous whistle superimposed upon the programme being received. It should not be confused with the heterodyne effect due to the overlapping of stations on adjacent wavelengths. In the superheterodyne receiver the interfering station brought in on the second channel may be many metres separated from the transmission being received. As the ability to suppress second channel interference is one of the greatest assets to sets of this class, the method of determining the ratio of second channel to the signal required is of advantage. Suppose the transmission required is radiated at 300 metres or 1,000 kilocycles and the intermediate frequency has a fixed tuning of 120 kilocycles. It must follow that the oscillator tunes to 1,000 kilocycles, plus or minus 120 kilocycles. As the oscillator has two tuning points capable of bringing in the same station, a flatly tuned input circuit may provide a second channel for a powerful interfering station of appropriate frequency.

Apply a small input signal from the generator connected as before at the required frequency. Note the attenuator setting and the strength of the output signal. Detune the generator and increase the attenuator approaching its maximum. The setting of the receiver must not be altered. Rotate the generator wavelength control either above or below its earlier position, dependent upon whether the oscillator frequency is above or below the signal frequency. When the signal is again heard, adjust the attenuator until the output reading is the same as before.

Sensitivity Tests of Different Receivers

By careful tuning and the use of reaction, the receiver under test is brought to its highest sensitivity, at the same time reducing the attenuator to obtain a definite meter reading. The test is repeated on a second set. The new attenuator setting which gives the same meter reading will indicate the comparative merits of the receivers.

SOUND RECORDING AT HOME

By ERIC J. RIGBY, A.M.I.E.T., M.T.R.A.

Fig. 1.—A Typical Home Recording Outfit.
This shows the " Cairmor " system in operation.

BEFORE the advent of electrical recording in 1924, the cutting of the record groove on the wax was accomplished by purely mechanical means; the recording artist was compelled to bellow into a horn-shaped trumpet. which collected the sound and concentrated it on to the diaphragm to which was attached a stylus for cutting the wax.

By this method the success of the recording was governed by the acoustic energy output available from the artists, who had to be grouped closely round the recording trumpet.

Since the development of electrical recording, however, the trumpet has been replaced by a microphone which converts the acoustic energy of the artist to electrical energy, which, amplified many thousands of times by a valve amplifier, is then reconverted to mechanical energy at the recorder.

This makes for a greater freedom from distortion, combined with the additional advantage that the artists can be arranged comfortably, and under more normal conditions, in front of the microphone.

This article is written to deal with recording in the home, and it will be found that remarkably good results can be obtained, using a minimum of impedimenta, whilst a little forethought in the matching of components will enable really excellent recording to be obtained.

Essentials of a Home Recording Equipment

The essentials of a home recording equipment are as follows :—

Microphone.
Amplifier.

Recording head.
Tracking attachment.
Stylus or cutting needle.
Gramophone motor.
Record material.

We will now discuss each of these in turn.

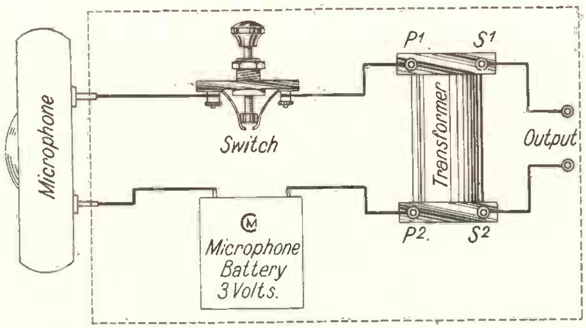


Fig. 2.—Diagram of Connections of the "Cairmor" Microphone Unit.

THE MICROPHONE

Since the microphone is the first link in your sound system, it will be obvious that the success of your results will depend largely upon its efficiency.

Microphones are many and varied, both in design and price, ranging from a simple carbon "button" microphone costing 5s., to a condenser microphone costing anything up to £100.

The Carbon Microphone

The carbon microphone, though a sensitive and efficient instrument, fails badly when absence of distortion is desired. It works on the principle of the air-pressure variations being changed into variations of electrical energy by changes in the resistance of carbon particles through which are passed a current of from 2 to 6 volts.

For a microphone to pass on perfectly undistorted sound to the amplifier, the resistance changes should be directly proportional to the air-pressure changes, and in the carbon microphone this is unfortunately not the case, mainly owing to the inertia of the diaphragm and to the fact that the resistance of the carbon particles is not entirely independent of the current passed through the microphone.

Furthermore, all carbon microphones will be found to possess a vibration period of their own, this usually lies in the neighbourhood of 1,000 cycles per second, and thus the response of notes in this portion of the musical scale is greatly emphasised.

Overcoming the Vibration Period of Carbon Microphones

This defect can be overcome to a certain extent by mechanical damping with rubber, which, however, results in loss of sensitivity, and by correction in the amplifier and recording head.

Very efficient and sensitive microphones of the carbon type can be obtained at varying prices, but probably the most satisfactory instrument for home use is the B.T.H. microphone.

Apart from its cheapness, it has the additional advantage of being fairly sensitive, and thus a large amplifier is unnecessary, whilst, furthermore, it is definitely more suitable for use in the home than the more expensive "condenser" type instrument.

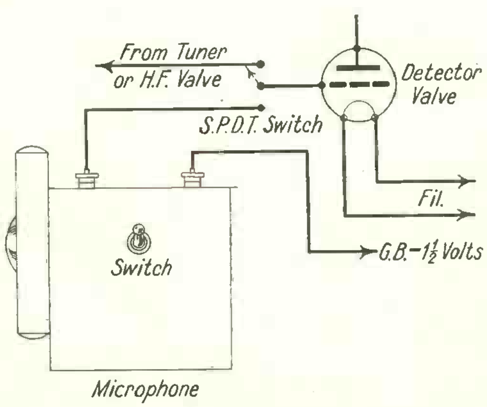


Fig. 3.—How an existing Battery-driven Wireless Set could be adapted for use with the "Cairmor" Microphone Unit.

The Condenser Microphone

A condenser microphone picks up sound at a very great distance, and very careful damping of the room is necessary in order to avoid reverberation — the

B.T.H. microphone, with its shorted pick-up, obviates this.

Whilst on the matter of microphones, it might be as well to mention a remarkably efficient instrument manufactured by Cairns & Morrison Ltd. This microphone is ideal for speech recording, and is well worth a trial; furthermore, it is sold complete with transformer and energising battery and is wired ready for instant connection to the input of your amplifier (see Fig. 2).

Having decided upon the type of microphone that you intend to use, we pass on to the question of suitable amplifiers.

THE AMPLIFIER

The power of your amplifier will, of course, depend upon the sensitivity of the microphone that you are using; with a Cairns & Morrison microphone your amplifier can be quite a simple affair, say a two-valve transformer-coupled unit, using a valve of the PM202 type in the output, such as that shown in Fig. 4.

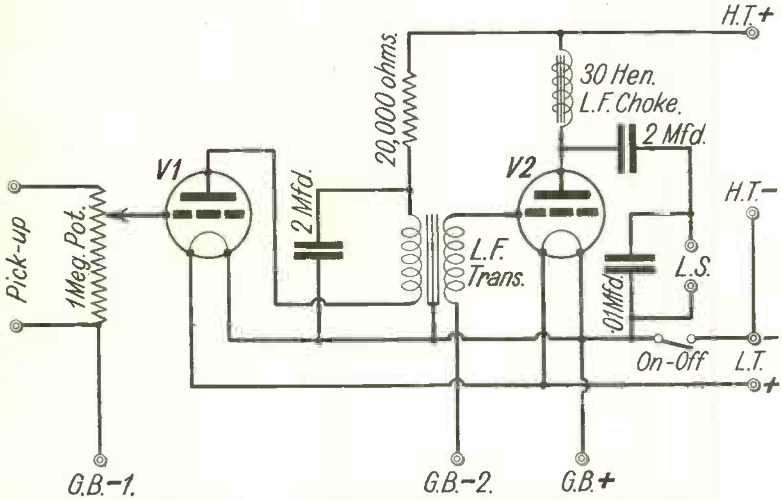


Fig. 4.—A Two-valve Transformer-coupled Amplifier Unit. Using a PM202 type output valve. An amplifier such as this would be suitable for use with a Cairns & Morrison microphone.

With a less sensitive microphone you will need something a little more ambitious, at least two R.C.C. stages coupled to two PM202 valves in push-pull; whilst with a condenser microphone you will require not only a pre-stage amplifier, but a main amplifier giving about 5 watts output.

Employing your Existing Radio Set

The design of your amplifier must be left to your own individual taste; you might even employ your existing radio set to good advantage (see Fig. 3), although if you wish to make anything like professional records it is recommended that you consider the matching of an amplifier to suit the characteristics of your microphone.

THE RECORDING HEAD

From the amplifier, the amplified impulses are fed to a recording head, which, for home recording purposes, can be an ordinary pick-up. The choice of pick-up is very important, for the damping plays a great part towards the success of your recording.

Heavily Damped Pick-up is best

In general, home recording calls for a heavily damped pick-up; this lessens the chances of overloading your disc, and increases the low-note response. There are many pick-ups that could be used for recording in the home, but only two that are definitely satisfactory: first the B.T.H. old type pick-up, sold without arm, and secondly the "Truvox," which is manufactured by Cairns & Morrison Ltd.

The "Truvox" is now specially made for recording purposes, and is damped very effectively, whilst it has the additional advantage of fitting the "Cairmor" tracking device.

THE TRACKING ATTACHMENT

The tracking attachment is a device which feeds the pick-up from the outside to the centre of the disc in the customary spiral groove; it can be obtained in many forms, but for practical reasons you should make sure that it is capable of tracking a full 10-inch disc, which enables you to make a record lasting three minutes. The tracking screw should be $5\frac{1}{4}$ inches long, and threaded for $4\frac{1}{4}$ inches with approximately twenty threads to the inch.

Fig. 5.—THE "SILVATONE" RECORDING MECHANISM.
The tracking gear and screws are built into a special chassis and motor.

How the "Cairmor" Tracking Attachment works

The "Cairmor" tracking attachment fulfils this condition adequately, being a small gear-box which plugs on to the turntable spindle of a gramophone with a "chuck" action, and is held secure by means of a support arm and steady pillar.

The gear-box communicates with a screw thread which lies horizontally to the turntable, and to this is clipped the recording pick-up.

As the turntable revolves, the gear-box causes the screw thread to turn, and the pick-up is thus gradually fed in towards the centre of the disc, the grooves being ninety to the inch. This attachment costs £1 7*s*. 6*d*.

THE STYLUS OR CUTTING NEEDLE

The next thing to be considered is the stylus or cutting needle; this may be of hard steel, sapphire or diamond. The hard-steel cutter is cheap and fairly efficient, but has the disadvantage of wearing very rapidly; this disadvantage is also present in the sapphire, though not to such a marked degree.

The diamond, though the most costly, for a good diamond cutter costs £1, is by far the most satisfactory, and consistent results are assured by its employment.

THE GRAMOPHONE MOTOR

The weight applied to the pick-up will depend upon the strength of your gramophone motor, which should be the strongest that you can obtain, for the deeper the cut the better the recording, although you must bear in mind that as you cut deeper, so must you increase the power applied to the recording head to secure good amplitude.

It is essential that the motor should pull with a weight of at least 8 oz. on the diamond, as otherwise the track will probably be too shallow to allow the play-back needle to hold the grooves satisfactorily. Any motor with a good strong spring will give satisfactory results. It is important when adjusting the stylus to make sure that the polished surface is on the record.

THE RECORD MATERIAL

Now we come to the all-important matter of the material on which the recording is to be done. After many years of experimenting, manufacturers have come to the conclusion that the hard aluminium disc is the most efficient for use in the home, by reason of its cheapness. Many other metals have been tried, including alloys, but none have been found to equal the aluminium, with the possible exception of copper, and this is, of course, too expensive.

A double-sided 10-inch disc of aluminium can be bought for 9*d*., and thus home recording is a reasonably cheap proposition. The record is ready for use immediately it has been recorded, and may be played back an indefinite number of times with a fibre, or Burmese, needle.

If you are able to obtain a really deep cut, you can even play back with a steel needle, provided that it is bent so as to "trail" at an angle of about 30 degrees to the record.

Using a diamond on a hard aluminium disc, the surface noise on the finished record is very slight, and under good conditions may be even less than on an ordinary commercial record.

Before attempting to "cut" the aluminium disc, it must be lubricated by the application of a thin coating of paraffin; this may be removed after the recording.

TECHNIQUE OF GOOD RECORDING

As in most things, the success of the recording will depend largely upon the ability of the operator; it is not merely a matter of sticking a microphone in front of the artist and hoping for the best—a great deal of skill and technique is called for.

One cannot put a microphone in a given position in a hall or studio and expect to get reproduced exactly the same quality of music as the ear would hear if placed in the same position, for the ear, with its automatic control of hearing, and with the assistance of the "binaural" effect, differs entirely from a microphone, inasmuch as,

(*a*) it is directive; two ears can be made to concentrate on the hearing in any particular direction;

(*b*) it is selective; it can concentrate on the things it wants to hear, and reject the things that it does not want to hear.

A microphone, however, must take everything that comes to it, whilst the distortions present in the microphone, amplifier and recorder, however slight, make the reproduction sound very much more reverberant than the original.

Where to place the Microphone

To obtain the same result with a microphone as with the ear, one should place the microphone at half the distance, or even less, from the artist. Usually, the quieter the sound, and the nearer the microphone is to the origin of sound, the better, hence the success of the "Crooners" on the radio.

Intelligent voice control is undoubtedly the prime secret of successful voice recording, and it is usually found that if speech is slightly slower, and each syllable articulated with more care than usual, that the results are considerably better.

This does not mean that one has to adopt a semi-preaching tone of voice, but rather to avoid any undue slurring of one word into another, *e.g.*, you should say "we are" rather than "we're."

Balance

The successful recording of musical instruments or groups of instruments depends upon that elusive quality of "balance"—nothing sounds worse than a singer whose voice is completely drowned by the piano accompaniment.

The study of records of first-class artists made by reputable firms wil assist you in forming ideas as to the relative strength that different sounds should be recorded at, and to duplicate their results only calls for the careful and correct placing of the artists around the microphone.

Output

Whilst on the matter of output, you must always feed the recorder through an output transformer to obviate the possibility of burning out the coils, or, alternatively, employ a choke output.

A more ambitious recording mechanism for really serious work is also made by Cairns & Morrison Ltd., and is called the "Silvatone."

The "Silvatone" is a sound piece of mechanism in which the tracking gearing and screws are built into a special chassis and motor. The motor is made especially strong to enable a really deep cut to be obtained, and the machine will track a complete 12-inch disc in addition to the smaller sizes.

RECORDING STRENGTH

The amount of output required to load your disc fully will depend upon how heavily your pick-up is damped, and upon the depth of the cut; a loud speaker may be wired into your output circuit and used as a monitor—this will give you a good idea as to what is going on the disc, whilst a little experience with your own particular machine will enable you to obtain consistently good results.

The Question of Copyright

A point which should be mentioned here, and which should be very clearly understood, is that wireless programmes and existing gramophone records are the property of the British Broadcasting Corporation and the Gramophone Companies respectively.

Any broadcast programme or gramophone record made *is liable to heavy reproductions fees*, especially in the case of a well-known artist. It must, therefore, be remembered that one is completely barred from such reproduction.

This means that home recording should be confined to the reproduction of one's own voice or music and those of one's friends and acquaintances.

Using Home Recording Apparatus with Home Movies

Even with the above-mentioned restrictions there is quite a wide scope for the legitimate use of Home Recording apparatus.

One application which immediately suggests itself is in connection with Home Movies. The appropriate sounds corresponding to any film can be recorded on discs whilst the film is being run through the projector.

Obtaining Synchronism

Special apparatus can be obtained which enables the projector to be driven in synchronism with the turntable of the recorder. Readers wishing to pursue this aspect further are referred to the monthly publication, "Home Movies."

Home Recording Apparatus for Lantern Lectures

Another interesting application is the use of Home Recording apparatus for making a set of records corresponding to a series of lantern slides. This enables one to give a modernised version of the lantern lecture which was so popular twenty years ago.

These are only a few of the advantages of home recording, and readers will doubtless have no difficulty in finding many uses for the apparatus for their future enjoyment.

THE STRAND RADIOGRAMOPHONE

By A. E. WATKINS

THE radio-gramophone described here is designed to give as fine a reproduction as possible, with an adequate number of stations. It possesses the following features:—

Adjustable band-pass tuning, variable-mu screened-grid H.F. amplification, power grid detector, push-pull output, dual speakers, A.C. mains operation.

Constructional Details

All the components have been either specially designed or selected for this particular instrument and the writer does not, therefore, advise any substitution.

Fig. 1.—THE COMPLETE RECEIVER IN OPERATION.

As this instrument includes push-pull output which is controlled by the patents, therefore the transformer which is recommended should be used, and by the purchase of this transformer the builder is granted a licence for the use of this patent. This is covered by the arrangement with the licensee and the transformer manufacturers.

How the Components are Mounted

On reference to the illustrations it will be seen that some components are mounted on the top of the baseboard, while others are mounted underneath; this is done as it considerably shortens the wiring to many of the components, saves considerable cramping, and allows the controls of the condenser, etc., to be grouped in a satisfactory manner to suit the front panel of the cabinet.

The Baseboard

The baseboard which is supplied with the cabinet is mounted on two $3\frac{5}{8} \times 1$ inch battens; this brings the baseboard to the required height and also leaves room underneath for the components, such as condensers and resistances.

Finding the Centre for the Tuning Condenser

After having screwed the battens on the ends, a line should be drawn right across the centre. This gives the correct centre for the tuning condenser. A line $4\frac{1}{2}$ inches each side of this centre line should then be drawn, and another 3 inches each side of the centre line. The advantage of drawing these lines is that the centre spindle of the control can then be placed true and parallel, so that when the instrument is put into the cabinet the knob will lay flat with panel.

Fit the Underneath Components First

All the components on the under side

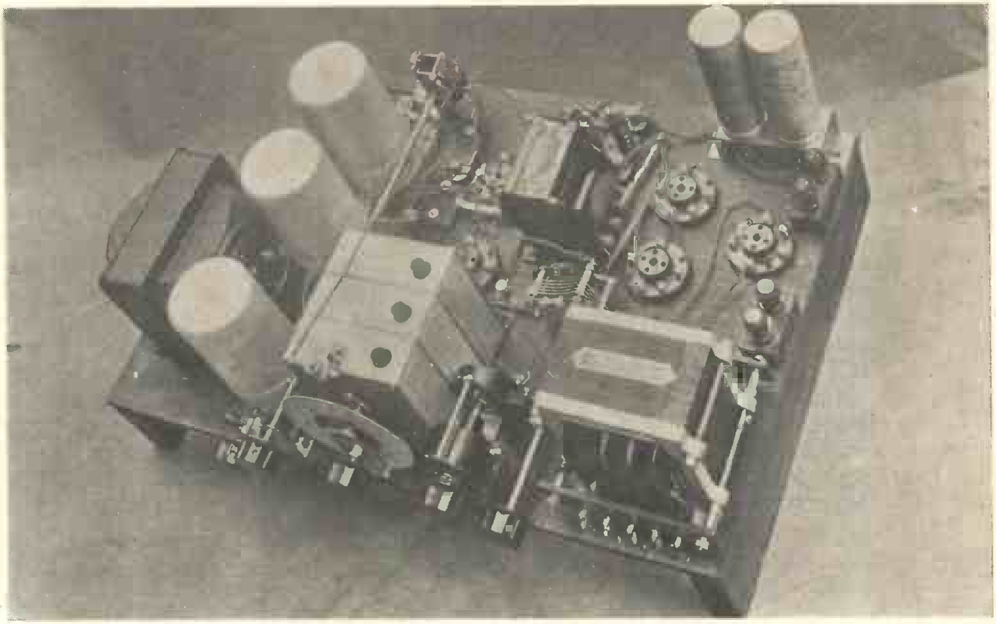


Fig. 3.—HERE WE SEE CLEARLY THE ABOVE BASEBOARD WIRING AND LAYOUT OF COMPONENTS ON THE BASEBOARD.

of the baseboard may be fitted first and laid out in accordance with the plan ; any slight variation in the distances will not matter, as there is plenty of room on the under baseboard, providing of course, that it clears the hole which has been

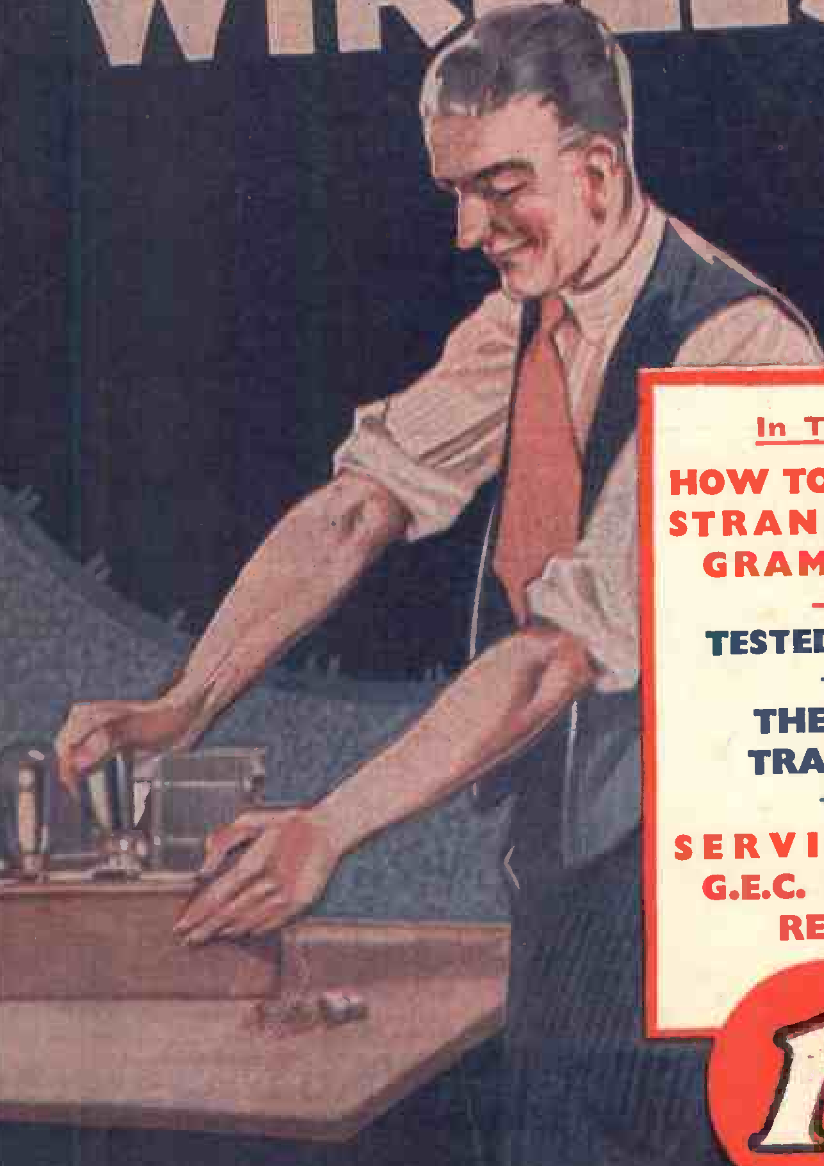
COMPONENTS REQUIRED FOR THE "STRAND" RADIOGRAMOPHONE

1 No. 1098 twin safety fuse holder with plug (*Belling & Lee, Ltd.*).
3 Terminal mounting blocks (*Belling & Lee, Ltd.*).
1 Aerial, Type "B" (*Belling & Lee, Ltd.*).
1 Earth, Type "B" (*Belling & Lee, Ltd.*).
1 H.T. positive (1), Type "B" (*Belling & Lee, Ltd.*).
1 H.T. positive (2), Type "B" (*Belling & Lee, Ltd.*).
2 Terminals pick-up, Type "B" (*Belling & Lee, Ltd.*).
1 "Matched Response" electrical pick-up, Mark III (*Bowyer-Lowe & A.E.D., Ltd.*).
1 pair Dual balanced speakers: F.M. 1000; F.7 1000·01B (*The British Rola Co., Ltd.*).
1 "Westminster" cabinet and baseboard (*Carrington Manufacturing Co., Ltd.*).
1 S.P. 3V. triple commodore condenser (*The Cyldon Radio*).
1 S.T.70 trimmer condenser (*The Cyldon Radio*).
1 B.B.1 Bebe condenser (*The Cyldon Radio*).
1 E.T.1 6-inch extension rod (*The Cyldon Radio*).
2 8 mfd. electrolytic, 400 volts working (*The Dubilier Condenser Co.* (1925), *Ltd.*).
2 2 mfd. paper, 200 volts working (*The Dubilier Condenser Co.* (1925), *Ltd.*).
3 1 mfd. paper, 200 volts working (*The Dubilier Condenser Co.* (1925), *Ltd.*).
2 ·001 mica (*The Dubilier Condenser Co.* (1925), *Ltd.*).
3 ·002 mica (*The Dubilier Condenser Co.* (1925), *Ltd.*).
1 ·0001 with grid leak clip and ·25 megohm grid leak (*The Dubilier Condenser Co.* (1925), *Ltd.*).
2 100,000 ohms resistance wire ends, $\frac{1}{2}$ watt (*The Dubilier Condenser Co.* (1925), *Ltd.*).

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS



In This Part

HOW TO MAKE THE STRAND RADIO-GRAMOPHONE

TESTED CIRCUITS

THE PHILCO TRANSITONE

SERVICING THE G.E.C. CARNIVAL RECEIVER

1/-

Part 31

IN 32 WEEKLY PARTS

PART 31.

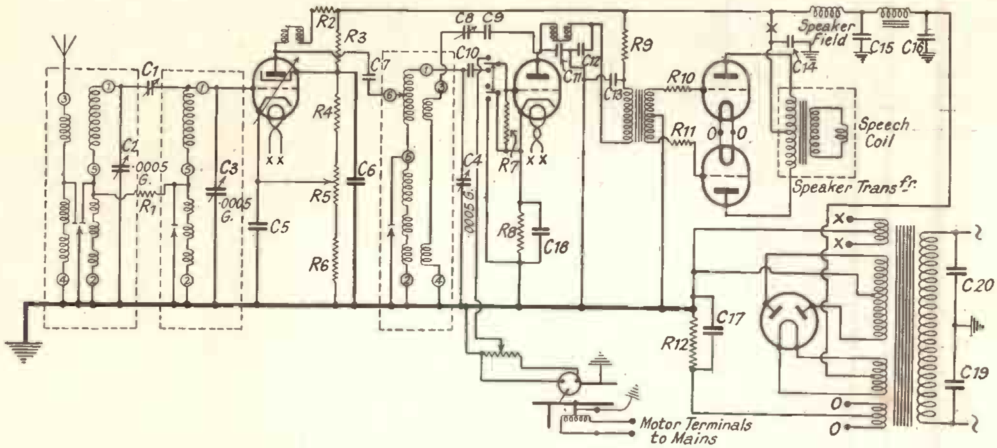


Fig. 3A.—Theoretical Circuit of the Strand Radiogramophone.

Values of components are as follows :—

CONDENSERS

C1	·00015 mfd.
C2, C3, C4	·0005 mfd. (Ganged)
C5	1 mfd.
C6	1 mfd.
C7	·0003 mfd.
C8	·0001 mfd. (Variable)
C9	·01 mfd.
C10	·0001 mfd.
C11, C12	·002 mfd.
C13	2 mfd.
C14	2 ,,
C15, C16	8 ,,
C17	2 ,,
C18	1 ,,
C19, C20	·0003 mfd.

RESISTANCES

R1	2 megohms
R2	30,000 ohms
R3	30,000 ,,
R4	10,000 ohms
R5	10,000 ,, (Variable)
R6	200 ohms
R7	·25 megohms
R8	1,000 ohms
R9	6,000 ,,
R10	100,000 ,,
R11	100,000 ,,
R12	750 ,,

Value of Pick-up Volume Control, 75,000 ohms, or to suit pick-up.

1 Transformer, Type AF6c (*Ferranti Ltd.*).

1 Sid Type 202a induction electric motor, complete with 12-inch unit motor plate (*The Garrard Engineering & Manufacturing Co., Ltd.*).

12 yards Twin screened anode wire (*Hart Bros., Electrical Manufacturing Co., Ltd.*).

24 yards 1/20 compo flex (*Hart Bros., Electrical Manufacturing Co., Ltd.*).

1 M.M.4V. valve, metallised (*Mullard*).

1 354V. valve (*Mullard*).

2 P.M.256 valves, Matched (*Mullard*).

1 D.W.3 valve (*Mullard*).

1 Transformer: 240 volts, 50 cycles; 350-0-350 volts, 120 m.a.; 2-0-2 volts, 2 amps.; 3-0-3 volts, ½ amp.; 2-0-2 volts, 2 amps. (*Partridge & Mee, Ltd.*).

1 set Ganged coils, Type C.W.R.G. (*Watmel Wireless Co., Ltd.*).

1 D.X.3 H.F. choke (*Watmel Wireless Co., Ltd.*).

1 D.X.2 H.F. choke (*Watmel Wireless Co., Ltd.*).

1 Screened smoothing choke (*Watmel Wireless Co., Ltd.*).

1 Dual potentiometer. Type D.M.S.7, complete with fixing bracket (*Watmel Wireless Co., Ltd.*).

1 Resistance 6,000 ohms, 12 m.a. (*Watmel Wireless Co., Ltd.*).

2 Resistances 30,000 ohms, 10 m.a. (*Watmel Wireless Co., Ltd.*).

1 Resistance 200 ohms, 10 m.a. (*Watmel Wireless Co., Ltd.*).

1 Resistance 10,000 ohms, 10 m.a. (*Watmel Wireless Co., Ltd.*).

1 Resistance 1,000 ohms, 12 m.a. (*Watmel Wireless Co., Ltd.*).

1 Resistance 750 ohms, 75 m.a. (*Watmel Wireless Co., Ltd.*).

3 Knobs (*Watmel Wireless Co., Ltd.*).

5 5-pin A.C. valve holders (*Whiteley Electrical Radio Co., Ltd.*).

1 Two pole switch, Type W.190/2 (*Wilkins & Wright, Ltd.*).

1 Extension rod, 13 inch (*Wilkins & Wright, Ltd.*).

drilled to bring the wiring through from the top components.

Drilling the Holes for the Wiring

It is advisable, though not essential, to drill these holes first, and they may be drilled from the plan given. There is one hole, however, which should certainly be cut first, and that is the hole to clear the moving vanes of the reaction condenser. A hole each end should be drilled with a centrebit and then the slot cut with a padsaw.

Fitting the Tuning Condenser

The first component on the top to be fitted should be the tuning condenser; this is placed right in the centre of the board; then fix the coils; the third component to be fitted is the reaction condenser, and a small metal bracket must be made so that it is the correct height of the switching rod of the coil. A piece of $\frac{1}{16}$-inch brass bent at right-angles is sufficiently strong. The radio-gramophone switch is fitted at the back, and a small angle bracket must be

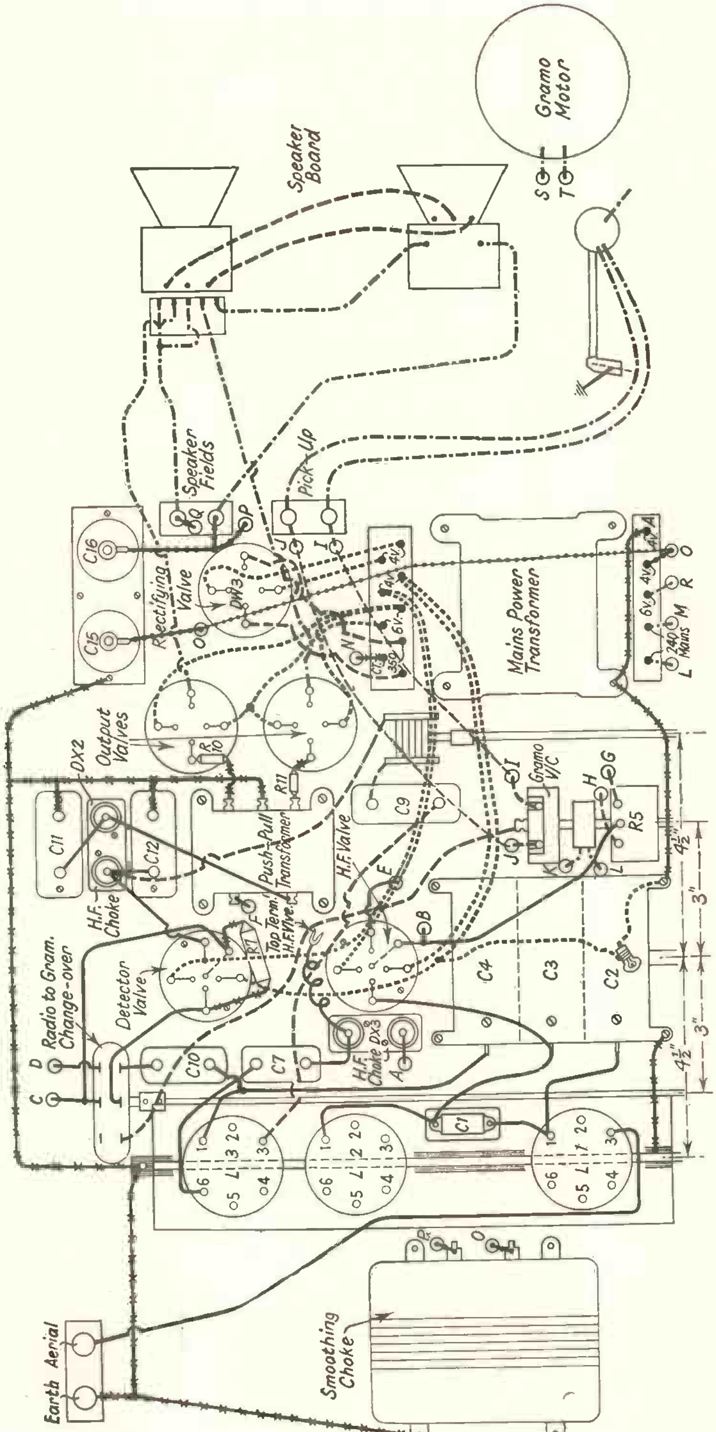


Fig. 4.—The above Baseboard Wiring Diagram.

made to carry this component and the height of the spindle must be the same as the volume control; the volume control is also mounted on a bracket, and this bracket will be supplied by the manufacturers of the control, but mention must be made of this when ordering.

This completes the components which are operated from the front of the panel.

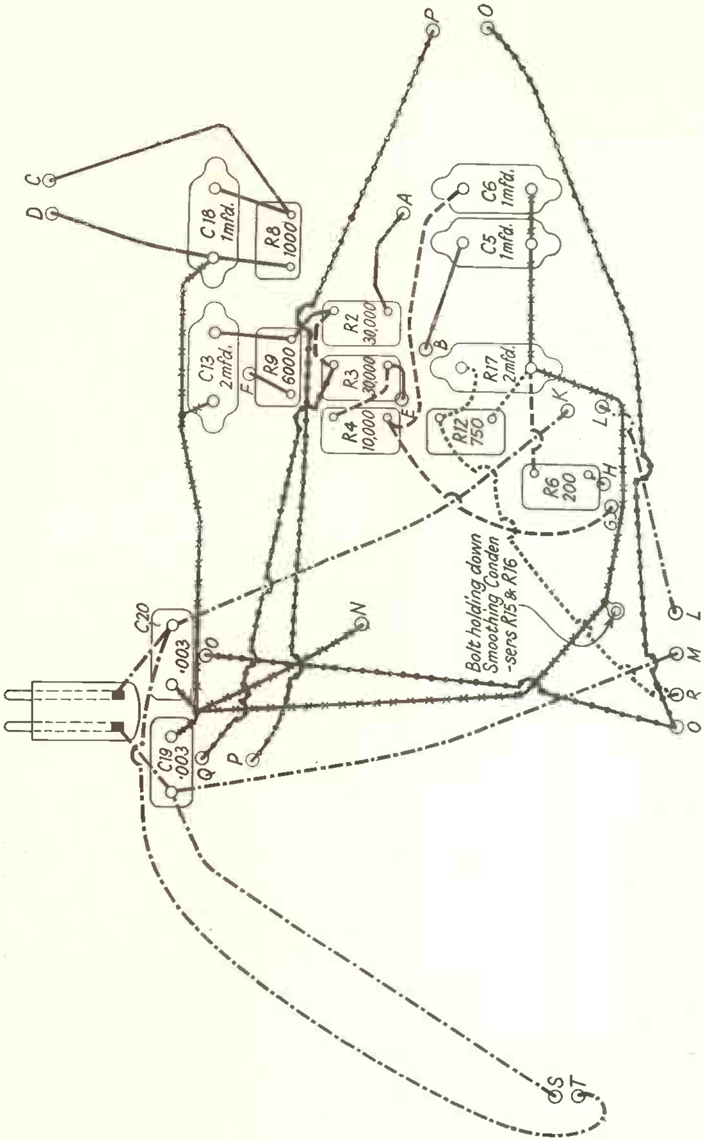


Fig. 5.—The Under Baseboard Wiring Diagram.

The Remainder of the Components

The other components may now be grouped around and screwed down in accordance with the plan, but they must be laid out loosely on the baseboard so as to obtain the correct placing.

Screws must not be too Long

Be very careful when screwing down the components to make sure that the screws which you use are not too long, so that they project through the baseboard, as otherwise they may make contact with the other components.

The Wiring

All the components being fixed, we will now proceed with the wiring.

For those who like to work from a theoretical diagram, the circuit is shown in Fig. 3A, and study of this is advisable in any case.

Wire to Use

Any suitable wire which is well insulated may be used for wiring up the components, but it is essential for the high voltage wires to be rubber insulated or with good quality sleeving, but a wire which is called "Slipback," made by Messrs. Hart Bros., Electrical Manufacturing Co., Ltd., or known as "Harbros" is very suitable. This wire has the

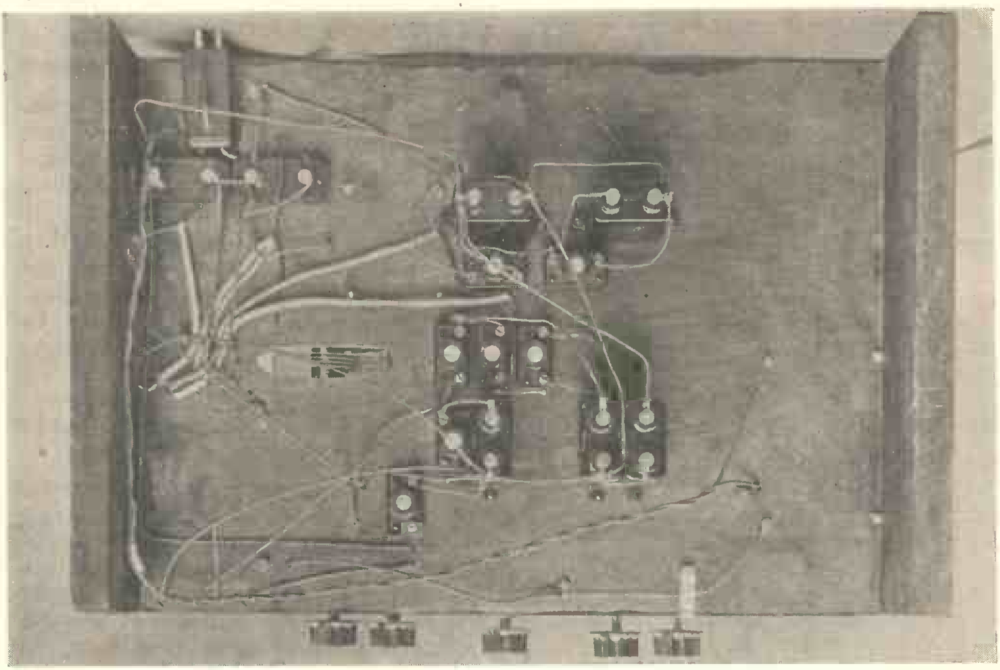


Fig. 6.—Here We See the Under Baseboard Wiring and Layout of Components.

advantage that, all that is necessary is to cut off a length and just push back the outer insulation covering, and being well tinned where necessary, it is easy to solder, and it is also perfectly suitable for clamping under the terminals. Keep all wires as short as possible, that is to say, from as near the point to point as possible, always remembering that any wires carrying a high-frequency current should be placed well apart, particularly those leading from the coil to condensers.

Why all the Terminals of the Coils are not Used

It will be noted that all the terminals of the coils are not used, the reason for this is, that they are internally connected, and where necessary automatically connected to earth. This saves considerable wire and adds to the selectivity by obtaining a good balance so that they correctly gang.

Between terminal "5" of the first band-pass coil a resistance is connected of approximately 2 megohms, and allows for greater transfer of energy on the long wave. The resistance is supplied already with the coils.

Condenser for Adjusting Selectivity

The small condenser C.1 mounted on the coil base is for adjusting the selectivity, the holes for fixing being already drilled on the metal baseboard.

After having wired up the instrument, carefully check over from point to point in accordance with the diagrams, as very often through an oversight a wire may be left off, and if the instrument was operating it may be that the valves would be ruined.

Pay Particular Attention to Earthing

Pay very particular attention that all the points which should be earthed are connected up, and particularly all the metal frames of the transformers, coils, and the metal supports of the electrolytic condensers are connected to earth.

From Fig. 3 it will be noted that the electrolytic condensers are carried on a metal support; this can be made of $\frac{1}{16}$-inch brass, bent at angles, so that when the insulated bush of the condenser is passed through, the centre electrodes clear the baseboard.

Be particularly careful to see that when the nut is screwed up tightly the outer cases of the condensers make effective contact with the brass support, as it is important that the outer cases are connected to earth.

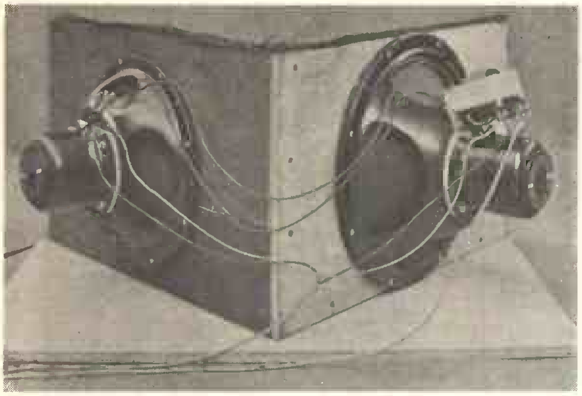


Fig. 7.—DETAILS OF THE LOUD SPEAKER WIRING.

What to do if Five-pin Valve Holders are Used

If five-pin valve holders are used for the push-pull output, and rectifier valves, take no notice of the centre terminal, but use the four connections as marked on the diagram.

When all the wiring is completed you may test by temporarily connecting up the speakers on the bench, and all adjustments can be made to the balancing condensers so that they are all correctly ganged.

The Balancing Condensers

The balancing condensers are the three black knobs on top of the variable condensers; these are each adjusted in turn, until the best signal strength is found. It is advisable to adjust on a weak signal so that the best and correct balance can be obtained.

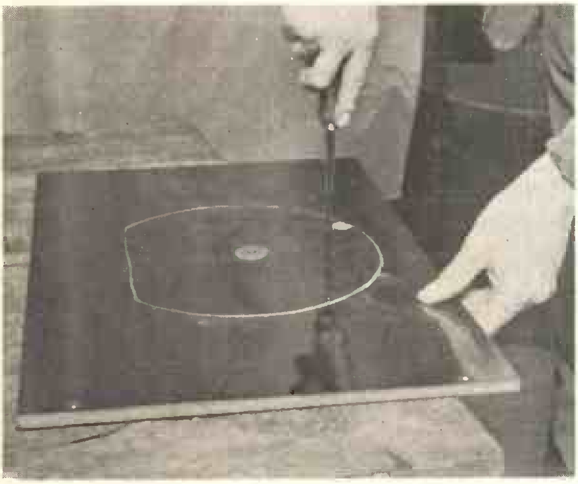


Fig. 8.—CUTTING THE HOLES IN THE FIVE-PLY-WOOD FOR THE LOUD SPEAKER DIAPHRAGMS.

CONSTRUCTING THE SPEAKER BAFFLES AND CABINET MOUNTING

As there is only one opening in the front of the cabinet, it follows that the two speakers cannot be fitted side by side on the front, but to overcome this difficulty, after due consideration, it was decided to fit these on a "V" baffle as shown in Fig. 7.

Obtain two pieces of five-ply-wood at least $\frac{3}{8}$ inch thick, $9\frac{3}{4}$ inches wide, and 7 inches long. In the centre of these two pieces, holes are cut, the size of the diaphragm of each speaker. The holes can be efficiently cut with a padsaw. The two baffle boards are then mounted on a baseboard which is 21 × 14 inches (this is also made of five-ply-wood which will be supplied with the cabinet).

Fixing the Baffles Securely

It is important that the baffles are securely fixed to the baseboard, and the best method is to place a 1-inch square fillet on each side of the speaker and also down the centre, where the two boards join, and securely glue and screw together. Along the front edge of the baffle board and along the top edging glue a piece of felt, so that when the whole speaker baffle is placed in the cabinet there will be no jarring due to vibration against the top board of the cabinet, for the baffle board fits close up against the top of the motor-board.

The Main Baseboards

The main baseboards of the speakers are carried on two bearers across the side of the cabinet. These bearers are screwed into position after the speakers are set, but before putting the baffle board into position the speakers should be screwed on to their respective baffles and all wires connected.

Fig 9.—BACK VIEW OF THE COMPLETED RECEIVER.

Should there be any cracks or openings of any appreciable size, when the baffles are fixed into the cabinet they should be packed round with cotton-wool.

Fig. 9 shows the position of the speakers.

The Wiring to the Loud Speakers

The leads from the fields are brought down to the terminal block, and it is advisable that screened wire is used for these leads, the covering and speaker frames being earthed. The fields are connected in series, as shown in the diagram, but to obtain the best effect it is sometimes necessary to change over the leads of one of the fields, that is, so that the current passes in the opposite direction; this may be found by trial, as it is important that both diaphragms move in the inward or outward direction together and if the polarity of one of the fields is different the reverse effect will be obtained.

The centre terminal of the push-pull transformer on the speaker is connected to the H.T. positive; take care it is connected the correct side of the speaker field. The two outer terminals are connected to the plate of each output valve, this is shown clearly in Fig. 4.

On this diagram also are shown the connections of the pick-up and the gramophone motor. The leads of these components should also be screened flex and the outer screen and motor should be earthed.

Fitting the Gramophone Motor

Unscrew the motorboard from the cabinet and take it out. Place the template supplied with the gramophone motor upon the baseboard, so that the turntable is 1 inch to the left of the centre, and mark round the dotted line as shown on template. Drill a hole in the centre, where the spindle will come, large enough to pass a wood screw through so that the board may be screwed on a box. Drill a hole near the dotted line with a centrebit and cut out the centre with a padsaw.

It will be seen that by screwing the motorboard down to a box or bench by a screw through the centre hole, it can be moved round as required during cutting and by this means the polished surface will not be damaged in any way. This method of holding the board down can also be employed when cutting the centre holes in the baffle boards for the speakers. This is more convenient than holding the wood in a vice.

Drilling the Front Panel of the Cabinet for the Controls to Pass Through

The cabinet makers have been supplied with a template so that the cabinet can be supplied already drilled should the reader so desire; the dimensions of holes are given in case the reader wishes to do this work himself. It will be noted that the holes for the control rods are ½ inch diameter; this size is used so as to allow for any slight variation in the position of the components, as the holes will be effectively covered with the knobs.

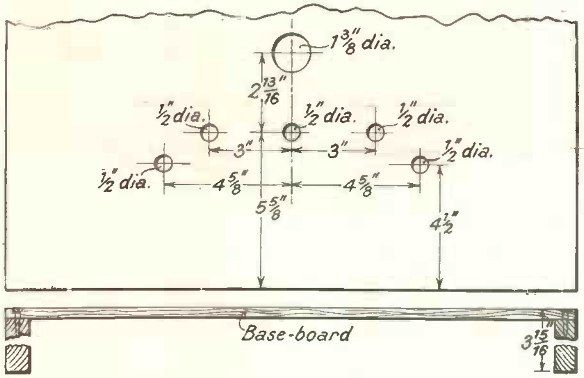


Fig. 10.—Dimensions of the Holes in the Front Panel of the Cabinet.

General Remarks

No instructions have been given for fitting the gramophone motor, as full instructions are supplied with the motor by the manufacturers which are quite simple to follow.

After you have seen that the instrument slides freely into the cabinet, before fitting the knobs, the rectifier valves and the screened-grid valve should be placed into position, as there is not sufficient room between the speaker baffles and the valveholders to fix these valves in place after the instrument has been slipped in, and as replacement of these valves will be only very infrequently, the trouble of having to remove the knobs is not any disadvantage. The output valve and detector valve can be placed into position last.

Test Results

As mentioned in the first part of this article the primary feature of this instrument was to be high quality reproduction, and the writer can confidently say that the reproduction of this instrument is the finest that can possibly be expected.

Output of Volume

The output of volume is considerably above that required for an average room; in fact, it is very rarely that the volume control can be used at full volume.

Quality

Another exceptional feature is that the quality both on record or on radio is extremely good and the balance of tone between the bass and treble is excellent, this, of course, is due to the balanced speakers and also the use of push-pull output.

Selectivity

The selectivity is of a high order and the local stations are cut out on 2 degrees of the dial, but, naturally, selectivity is dependent upon the adjustment of the condenser between the band-pass coil, and also the size and position of the aerial.

Tests have been carried out on two aerials, one an extremely large and good one and another a poor aerial within 10 miles of Brookmans Park.

On local stations, of course, no reaction whatever is necessary.

Absence of Atmospherics

When receiving foreign stations reaction is made use of and quite a number of stations come in quite clearly and distinctly and quality of reproduction is good; also atmospheric noises are at a minimum, the reason for this being, that there is only one stage of H.F. amplification.

This was one of the reasons which decided the writer to employ only one stage, because if extra stages of H.F. amplification are added, background noises are increased very appreciably to the detriment of the quality of reproduction.

SERVICING

THE G.E.C. "CARNIVAL" RADIO-GRAMOPHONE FOR A.C. MAINS (B.C. 3338).

THE instrument comprises a three-stage all A.C. mains operated receiver, energised moving-coil loud speaker, gramophone pick-up and an electrically-driven gramophone turntable with automatic stop.

Mains Aerial

The mains may be used as an aerial by inserting a shorting link (provided with the receiver) in the sockets marked " Mains Aerial " (see Fig. 2). This connects one side of the A.C. supply to the aerial terminal of the set through the small condenser C25 (0·001 mfd.).

External Loud Speaker

Terminals are provided at the back of the set for the connection of an additional loud speaker externally.

This is choke coupled through the condenser C21, the primary of the moving-coil speaker input transformer being used as the choke. Speakers for use externally must have an impedance between 7,000 and 10,000 ohms. If the impedance is less than this, a suitable step-down transformer must be used.

Valves

The receiver utilises four valves, of which one is the rectifier. These are as follows :

Osram M.S.4B. indirectly heated screen-grid H.F. valve, Osram M.S.4B. indirectly heated screen grid detector valve, Osram PT4 directly heated super power pentode output valve, Osram U.14 full-wave rectifying valve. The M.S.4B. valves may be either of the clear or metallised variety.

Fig. 1.—THE GECOPHONE " CARNIVAL " ALL ELECTRIC RADIO-GRAMOPHONE FOR A.C. MAINS.

Aerial Circuit

The aerial is loosely coupled *viâ* a small semi-variable condenser (C1) to the tuned grid circuit of the H.F. valve, V1. The tuning condenser C3 is ganged to the detector circuit tuning condenser C10.

Aerial Series Condenser C1

This condenser is pre-set at works to give maximum efficiency on an average aerial. Where the aerial in use differs widely from an average aerial, this condenser may require slight re-adjustment. The condenser is illustrated in Fig. 8 and is located towards the front of the left-hand side of the chassis on the left of the wave-change rod.

It is adjusted by turning the set screw in the centre, for which purpose it is essential to use a long insulated screwdriver.

A station on about 220 metres which is sufficiently weak to necessitate the volume control being turned up close to oscillation point should be tuned in, and this condenser adjusted for maximum signal strength.

H.F. Coupling to Detector Valve

This is effected by an H.F. transformer

with the secondary tuned by condenser C10.

Detection

The screen-grid detector operates on the leaky grid principle by means of C8 (0·0002 mfd.) and R10 (2 megohms).

Volume Control and Reaction

These are simultaneously controlled by the 8,000-ohm potentiometer R1. This is connected between the aerial and one side of the reaction coil with the moving arm earthed.

How to Replace Volume Control

To replace the volume control commence by removing the chassis from the cabinet. The volume control forms part of a complete assembly which includes the brass mounting and the mains switch. Unsolder the leads to the switch and to the potentiometer. Remove the nuts from the two bolts holding the brass mounting to the chassis.

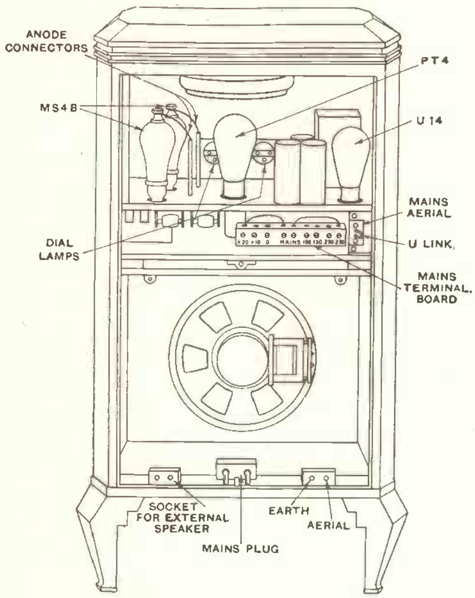


Fig. 2.—Rear View of the Set with the Back removed.

Pick-up Circuit

Volume is controlled by the 25,000-ohm potentiometer R8. Bias for the detector valve is provided by R12 and is supplied by closing the switch contact across the detector grid tuned circuit. The closing of this switch also short circuits the R.F. section of the receiver.

How to Remove Pick-up

The pick-up, tone arm and leads are one unit. Unsolder the leads at terminals H and J on the chassis (see Fig. 5) and remove the three round-headed bronze wood screws at the base of the tone-arm support.

The leads can now be pulled through from the interior of the cabinet and the pick-up and tone arm removed.

L.F. Coupling Circuit

This consists of the transformer T3 which is parallel fed by R9 (20,000 ohms) and C17 (0·1 mfd.).

Output Circuit

Coupling to the loud speaker is effected by the step-down transformer T2.

A heterodyne filter (L, C18, C19, C20) is incorporated in the anode circuit of the output valve.

Power and Smoothing Circuit

H.T. is provided by the full-wave rectifier V4. The L.S. field, the L.F. choke, C22, C23 and C24, provide the requisite smoothing. These condensers are each 8 mfd. and are of the electrolytic variety.

Loud Speaker

This is of the low-impedance type matched to the pentode by the transformer T2. The field is connected in the main H.T. positive supply line and acts as a smoothing choke.

To test whether loud speaker is faulty connect a speaker that is known to be O.K., externally or across terminals CD of T2 Fig. 5. Bad reproduction may be caused by a dirty airgap, a damaged cone, or the speech coil being out of centre.

The speech coil is centred by slackening the grub screw in the centre of the pole piece and moving this into such a position that the speech coil will move freely in and out. It should not be undertaken, however, unless a correct gauge is available to check the accuracy of adjustment.

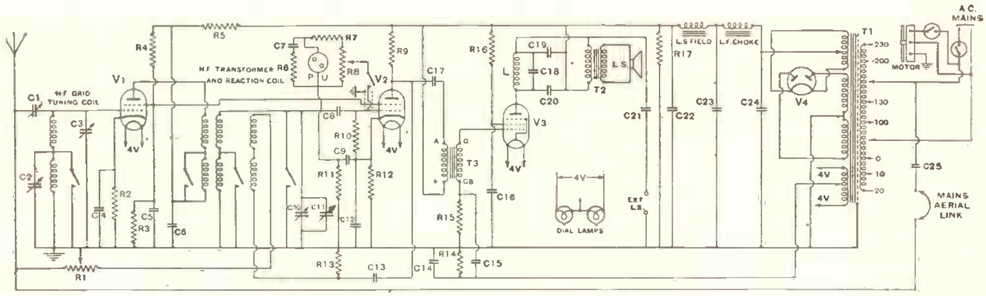


Fig. 3.—THEORETICAL CIRCUIT OF THE GECOPHONE "CARNIVAL" RECEIVER.

This instrument comprises a three-stage all A.C. mains operated Receiver, energised moving-coil loud speaker, gramophone pick-up, and an electrically-driven gramophone turntable with automatic stop. The aerial is loosely coupled *viâ* a small semi-variable condenser to the tuned grid circuit of the H.F. valve.

VALUES OF COMPONENTS USED IN THE GECOPHONE "CARNIVAL" RECEIVER

Details of Condensers

C1	0·00002 mfd.	C13	0·001 mfd.
C2	Trimmer (L.W.)	C14	1 mfd.
C3	0·00058 mfd.	C15	1 mfd.
C4	0·25 mfd.	C16	1 mfd.
C5	0·25 mfd.	C17	0·1 mfd.
C6	0·25 mfd.	C18	0·0005 mfd.
C7	0·003 mfd.	C19	0·003 mfd.
C8	0·0002 mfd.	C20	0·003 mfd.
C9	0·25 mfd.	C21	1 mfd.
C10	0·00058 mfd.	C22	8 mfd. Elect.
C11	Trimmer for C10	C23	8 mfd. ,,
C12	0·25 mfd.	C24	8 mfd. ,,
		C25	0·001 mfd.

Details of Resistances

R1	8,000 ohms	Pot.
R2	400 ,,	G.B. V1
R3	50,000 ,,	½ W.
R4	30,000 ,,	1 W.
R5, 16	15,000 ,,	1 W.
R6	10,000 ,,	½ W.
R7*	100,000 ,,	½ W.
R8	25,000 ,,	Pot.
R9	20,000 ,,	1 W.
R10	2 megohms	½ W.
R11, 15	100,000 ohms	½ W.
R12	200 ,,	G.B. V2
R13	120 ,,	—
R14	260 ,,	G.B. V3
R17	45,000 ,,	3 W.

* In some models, 50,000 ohms ½ watt.

Approximate D.C. Resistance of Miscellaneous Components

L		880 ohms.
T3 Primary	1/5	1,100 ,,
T3 Secondary		8,000 ,,
T2 Primary		400 ,,
T2 Secondary		0·4 ,,
L.S. Field		1,160 ,,
L.F. Choke		630 ,,

Miscellaneous Voltages (Figs. 5 and 6)

	Voltage.		Voltage.
C24	395 V.	T1 bet. 14 & Frame	375 V. A.C.
C23	360 V.	T1 ,, 15 & Frame	375 V. A.C.
C22	295 V.	T1 ,, 8 & 10	2 V. A.C.
T2	280 V.	T1 ,, 9 & 10	2 V. A.C.
Term D		T1 ,, 11 & 12	2 V. A.C.
		T1 ,, 11 & 13	2 V. A.C.

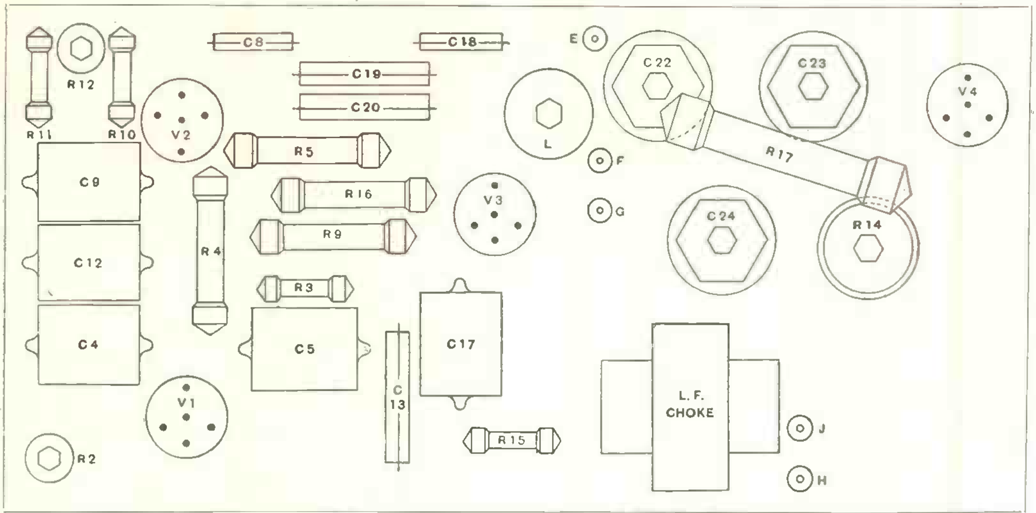


Fig. 4.—How the Components are placed on the Baseboard.

How to Remove Loud Speaker from Cabinet

Unsolder leads at terminals ABCD of T2 and the black earth lead on the loud speaker chassis.

Remove the three bolts at the periphery of the bowl.

It is not necessary to remove the baffle or to touch any of the screws holding the baffle to the cabinet.

How to Remove Chassis from Cabinet (See Fig. 5)

Remove back by unscrewing the four milled thumbscrews.

Remove control knobs by slacking grub screws.

Unscrew and remove radio-gramophone switch knob at front of cabinet.

Remove the six chassis holding-down bolts, the heads of which are located on the underside of the wooden platform supporting the chassis.

Withdraw the chassis sufficiently to render accessible terminals L and M at the side. Unbolt the earth tag

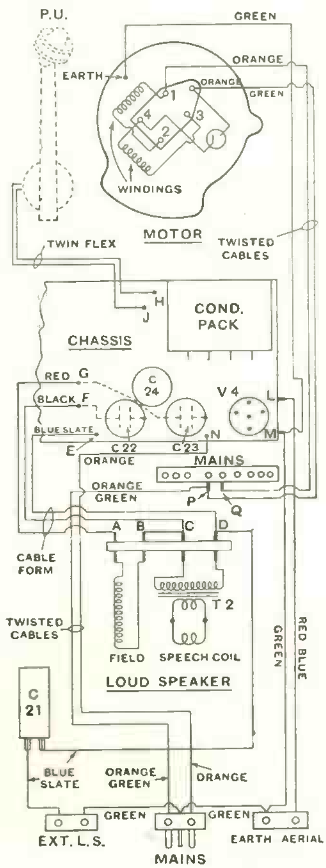


Fig. 5.—Details of External Wiring.

M (it is not necessary to unsolder the green earth leads).

Unsolder aerial lead from terminal L.

Unsolder pick-up leads at terminals H and J.

Unsolder leads to terminals E, F and G.

Unsolder the orange mains lead at the terminal N (situated on the underneath side of the deck). Unsolder the three leads at terminals P and Q on the underside of the mains terminal block.

The chassis should now be resting quite free on the two rectangular supporting battens and may be withdrawn.

When replacing the chassis, the following points should be observed. Place the batten with the green baize on the left-hand side (from the rear) in such a position that the coil cans on the chassis will rest on the baize.

Of the six holding-down bolts, first locate the front bolt on each side.

Preliminary Tests

If the receiver fails to operate on radio, check whether operation on pick-up is normal.

If there are no results on pick-up the fault must lie in either the L.F. amplifying portion of the receiver, in the loud speaker or in the H.T. supply (if there is any doubt about the operation of the pick-up test with a pair of headphones).

Proceed by testing loud speaker as described in the previous section headed "Loud Speaker."

If this is O.K., check the H.T. supply.

How to Test the High-tension Supply

Connect a voltmeter between the projecting terminal in the base of condenser C24 and frame. This should read about 380/400 volts. Unsolder lead A on the loud speaker terminal strip and check current in this circuit. This should read 55/60 m.a.

If the H.T. supply has failed, first try a new rectifying valve and then proceed to test the A.C. voltages applied to it. See Fig. 6 and Table above. If all the above points are O.K., check the low-frequency choke and the primary of T2 for continuity.

If O.K., test the resistance from C24 to frame.

This should read 30,000 to 35,000 ohms.

If this is much lower, suspect one of the electrolytic condensers.

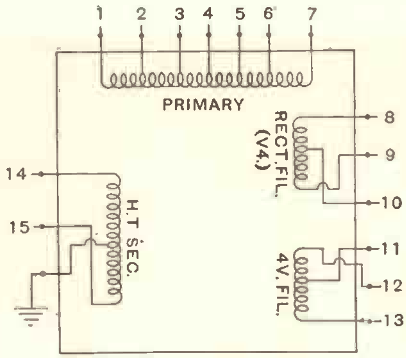


Fig. 6.—The Mains Transformer Connections.

1	White	230 V.	To Mains Input Terminal Strip.
2	Blue White	200 V.	
3	Red Brown	130 V.	
4	Green	100 V.	
5	Black	0	
6	Red Blue	10 V.	
7	Orange Green	20 V.	
8	Red Blue	.	To V4 Valve Holder Filament Connections.
9	Black . .	.	
10	Orange Green.		To C24
11	Blue White	.	To R14
12	Green . .	.	To V3 Valve Holder (Filament)
13	Brown		
14	Red . .	.	To V4 Valve Holder, Grid and Plate.
15	Red Brown .	.	

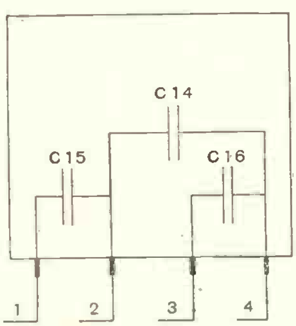


Fig. 7.—The Condenser Pack.

Lead.	Other end wired to.
1	R15
2	R14
3	V3 valve holder (screen)
4	R14 (earthed side)

Testing and Replacement of Electrolytic Condensers

Three electrolytic condensers are incorporated in the circuit, viz., C22, C23 and C24. Their positions on the chassis will be found in Fig. 4.

In these condensers the projecting spindle in the base forms one of the external connections and the metal case the other.

To test, isolate the condenser from the rest of the circuit by removing leads from the projecting spindle. Test the insulation with the ohmmeter, taking care to connect the positive terminals of this instrument to the projecting spindle. If this is much less than 400,000 to 500,000 ohms, replace condenser by unscrewing the large hexagonal nut in the base. When fitting a new condenser, make sure that the case is making good contact with the chassis.

Checking Pentode Power Supply

The anode current should be 30/32 m.a.

Anode current failure may be due to screen

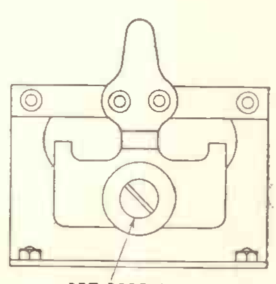


Fig. 8.—The Trimming Condenser.

voltage failure. Test this with voltmeter.

If the main H.T. supply is O.K., failure of screen volts will be due to breakdown of R16 or C16 (see Condenser Pack p. 1460). If, however, it is the anode voltage that has failed, check the choke L and the grid-bias resistance R14 for continuity.

If anode current is high, check R15 and the secondary of the L.F. transformer for continuity.

Condenser Pack

The internal connections are shown in Fig. 7.

To remove, unsolder leads and remove the four bolts holding this down to the chassis.

Checking the L.F. Amplifying Circuit

This is best performed with a pair of phones. Place these between the grid of the pentode valve and frame. If there are no signals here place phones across the primary of the L.F. transformer. If signals here are O.K., check the secondary of the transformer for continuity. If there are no signals on the primary, check the detector valve circuit.

Checking Detector Valve Circuit

Check anode current. If low or no reading at all is obtained test anode voltage. If anode voltage has failed suspect R.9.

If anode voltage is O.K. test screen voltage.

Failure of screen voltage may be caused by R4 or R5 breaking down or by a short circuit at C5.

High screen volts will be due to R3 failing.

Table of Voltages and Currents

The undermentioned readings are for the set operating under normal conditions (but not oscillating) and with no signal tuned in. Unless otherwise stated, all voltage readings are D.C. and taken from frame. Values are approximate only. D.C. readings up to 300 volts taken with 0—300-volt voltmeter of resistance 1,000 ohms per volt; readings over 300 volts taken with 0—600-volt voltmeter of same resistance standard.

Valve.	From Frame to	Voltage.	Current (m.a.).
V1	Plate	190	3·1
	Screen	80	1·0
	G.B.	1·6	
V2 (Radio)	Plate	190	4·4
	Screen	80	1·0
V2 (Gramo.)	Plate	200	3·8
	Screen	80	0·8
	G.B. (across R12)	0·9	
V3	Plate	250	32
	Screen	180	8
	G.B. (across R14)	11	
V4	Grid to frame	375 V. A.C.	
	Plate to frame	375 V. A.C.	

Filament Voltage is 4 volts A.C. throughout.

Testing Radio-frequency Section

If the aerial is placed on the tuning circuit side of C8 the receiver should operate like a very flatly tuned two-stage set. If no results are obtained check C8 (by substituting another condenser) and R10, also tuning coils for continuity and defective connections. If O.K., tap the aerial back to the anode of the H.F. valve when tuning should be a little sharper, but signals rather weaker. No signals here indicate a defective H.F. transformer primary.

If Set does not Oscillate

This may be due to the reaction feed condenser C13 being open circuited. Check by substituting another condenser.

A tendency to instability may be due to one side of R13 not earthing. Resolder joint if necessary.

Checking H.F. Valve

If the detector and L.F. portions are O.K. screen voltage will be correct as the screens of both H.F. and detector valves are connected together. Anode voltage failure can only be caused by a defective H.F. transformer primary or a disconnection in this circuit.

If good signals are obtained with the aerial placed on the grid of the H.F. valve but tuning is flat when the aerial is connected to the aerial terminal examine C1 for broken mica dielectric. This is replaced by withdrawing the set screw.

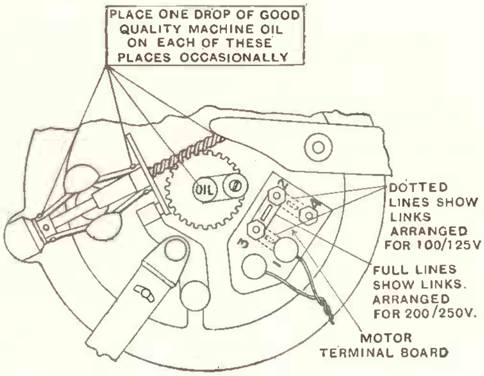


Fig. 9.—The Gramophone Motor.

Showing arrangement for adjusting voltage to that of the supply mains.

ADJUSTMENT AND MAINTENANCE OF GRAMOPHONE MOTOR

1. Motor Connections

The instrument is sent out connected for 200/250 volts, as indicated by the solid lines in Fig. 9. For 100/125-volt supplies, the two links (one over the other) must be removed from terminals 2 and 3 and placed separately on terminals 2 and 4 and 1 and 3, as shown by the dotted lines in Fig. 9.

2. Lubrication

The main motor bearing is lubricated *viâ* the small hole in the end of the turntable spindle, covered by a plug marked "oil." Remove this plug and inject one or two drops of best quality machine oil. The governor bearings should also be lubricated occasionally, while a drop of oil should be placed periodically on the governor felt pad.

3. Adjustment of Speed Regulator

Adjust speed regulating arm until motor speed is 78 r.p.m. (as checked by a stroboscope or some reliable form of speed indicator). If the pointer on the regulating arm now does not indicate 78 r.p.m., slacken the screw B on the regulating arm (see Fig. 10). This allows the arm to move without altering the position of the brake pad. Adjust pointer to 78 r.p.m. and retighten screw.

4. Applications of Automatic Stop

The switch will only stop the motor automatically when records having "spiral" run-in or "eccentric" finishing grooves are used. With other types it is necessary to push the pick-up arm against the short lever by hand to stop the motor, before returning the pick-up to its rest.

The receiver is sent out with the switch set to operate on records from 8 to 12 inches in diameter.

5. Instructions for Removing Motor

It is not necessary to remove chassis. Commence by removing turntable. Disconnect mains and earth leads. Unscrew and remove the five bronze counter-sunk bolts on the circumference of the motor plate. These are held by nuts and washers on the underside of the motor platform and are accessible from the inside of the cabinet. The motor is now free to be lifted out.

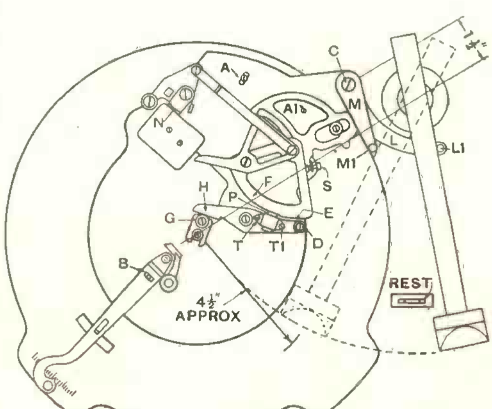


Fig. 10.—The Essential Parts of the Gramophone Motor.

Replacement of Dial Lamps

Two dial lamps are fitted (see Fig. 2). These are Osram 3·5V. 0·3 amp., and are of the screw-in flash-lamp type. It is not necessary to remove the chassis in order to replace them as they are rendered accessible by removing the back of the set.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION XIV—SELECTIVITY

THE selectivity of a radio receiver is its property of discriminating between signals of different frequency, or wavelength, when it is tuned to receive signals of one particular frequency, or wavelength. Thus, suppose that we have two broadcasting stations, A and B, working on wavelengths of 250 and 300 metres, and that we tune a receiver to A's wavelength. The receiver will also respond to B's signals on 300 metres, and the extent of the response to this unwanted signal will be a measure of the selective properties of the receiver. If the response to B's signals is so small that no audible interference with A's signals is observed, then we may say that the receiver is sufficiently selective to discriminate completely between the two stations.

If now we are able to change B's wavelength so that it approaches nearer to 250 metres, we shall observe that, when a certain wavelength is reached, interference from B becomes audible. As the wavelength of B is made closer still to 250 metres, the interference increases, and in order to eliminate this interference it would be necessary to make certain adjustments to the circuit of the receiver—*i.e.*, to improve its selectivity.

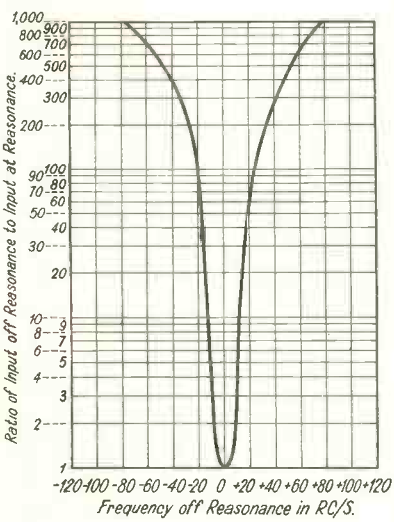


Fig. 1.—A TYPICAL SELECTIVITY CURVE OF A RECEIVER.

How Selectivity is usually expressed

It is very difficult to define selectivity so that it can be measured in definite units. We cannot say that the selectivity of a certain instrument is 10 units, and the selectivity of another is 15 units. The behaviour of tuning circuits is such that the selectivity depends on the particular portion of the tuning range considered; it also depends on the type of detector employed in the receiver. Hence selectivity is usually expressed in the form of a graph: the graph is obtained experimentally, and the process demands a considerable amount of laboratory equipment. For this reason a selectivity curve cannot be plotted by the ordinary experimenter, indeed, even certain radio manufacturers in this country are without the necessary facilities for making a selectivity test on their products.

How Selectivity is Determined

The selectivity is found to vary with the wavelength considered, and hence several graphs are usually drawn, each representing the selectivity at a different part of the tuning range of the receiver. The

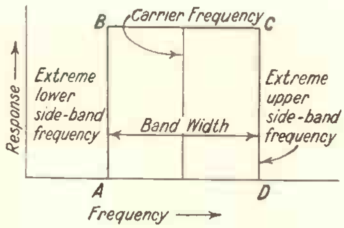


Fig. 2.—Ideal Response Curve for a Circuit.

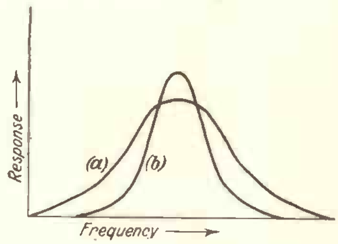


Fig. 3.—Two Types of Curve that may be obtained by different Choice of Circuit Constants.

a, with coil of poor efficiency ; *b*, with highly efficient circuit.

procedure for making the test is best described by quoting from the 1931 Year Book of the Institute of Radio Engineers : " The selectivity is determined by tuning the radio receiver to each standard test frequency in succession, . . . and measuring the radio frequency input voltage necessary to give normal test output at a series of carrier frequencies in steps not greater than 10 kilocycles at least up to 100 kilocycles on either side of resonance, . . . For each standard test frequency a graph is plotted with carrier frequency as abscissæ and the ratio of input off resonance to input at resonance, as ordinates. The scale of ordinates should be logarithmic . . ."

A Typical Curve and what it shows

Fig. 1 shows a typical selectivity curve of a receiver. It will be seen that, at 8 kilocycles from resonance, the signal intensity must be twice that at resonance in order that the same output may be obtained. At 20 kilocycles from resonance this figure is of the order of 100. That is to say, the receiver will probably be able to discriminate between two stations of equal field strength and separated by 20 kilocycles, but could not differentiate between them if their frequency separation were only 8 or 10 kilocycles. In the case of two stations whose field strengths are in the ratio of 1 : 1,000, the weaker station could not be received satisfactorily even when the separation was 80 kilocycles, for the curve shows that an equal audio output would be obtained from two stations whose field strengths and frequencies were related in this manner. The curve cannot tell us how great would be the response of the receiver to an interfering signal of *any* field strength relative to that of the desired station, and hence is not an absolute measure of the performance of a receiver.

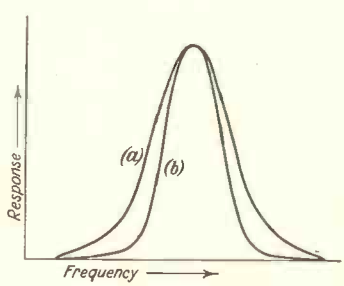


Fig. 4.—This shows the effect on the Overall Response of employing Two Single Circuits connected in Cascade.

Response Curve of a Simple Circuit

Let us now consider the response curve of a simple circuit instead of the response of the complete receiver. The response curve is a curve showing the voltage available across the circuit, *i.e.*, the response of the circuit, at different frequencies, due to a signal of fixed frequency. We can either plot response curves by experiment or we may calculate the shape of the curve from a knowledge of circuit impedances. It is evident, therefore, that if we restrict the definition of the selectivity of an instrument to the selectivity of its tuned circuits, the question of expressing selectivity in definite units becomes much easier.

Side-band Waves

In dealing with the methods of detection of wireless signals we saw that a modulated wave comprised a radio frequency oscillation whose maximum amplitude varied at an audio frequency. It can be shown that the modulated wave is equivalent to several waves, called the carrier wave and the side-band waves. There are two side-band waves for every note of modulation in the signal, an upper and a lower side-band wave. Each wave has a frequency which is definitely related to the carrier and modulation frequencies. Thus, in the case of a signal whose carrier frequency is 1,000,000 cycles, and which is modulated by a single note of frequency 1,000 cycles, the complete signal is equivalent to three waves of frequencies: 1,000,000 cycles, 1,001,000 cycles, and 999,000 cycles. The first is the carrier wave, the second the upper side-band wave, and the third the lower side-band wave. These waves have actual existence in a receiving circuit, and appear to exist as separate waves in the ether: the evidence is fairly conclusive but we cannot deal with it here.

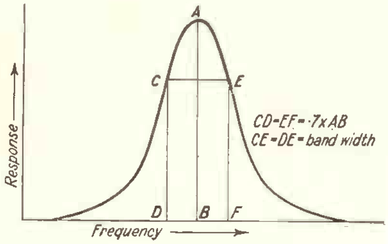


Fig. 5.—Band Width of a Response Curve.

Range of Waves transmitted by a Station

In the case of a station which is transmitting speech and music, a large number of waves are radiated. Suppose that the highest audio frequency dealt with in the studio is 5,000 cycles, then a station with a carrier frequency of 1,000,000 cycles radiates waves with frequencies ranging from 995,000 cycles to 1,005,000 cycles, *i.e.*, it radiates a band of waves covering a band width of 10,000 cycles, or 10 kilocycles.

In order to receive these waves, which comprise the complete signal, our tuning circuits must be capable of response to waves over this band width. In order, also, that the audio frequencies may not be distorted relative to each other the response must be as uniform as possible over the entire band width. Further, in order that we may not experience interference from other waves it is desirable that the response of the tuned circuits ceases, as abruptly as possible, at the extreme ends of the band.

Ideal Response Curve

Fig. 2 shows the ideal response curve for a circuit. The horizontal portion, BC, ensures an even response to all the audio frequencies, and the vertical portions, BA and CD, ensure an abrupt " cut-off " at each end of the band.

At this juncture it is convenient to point out that the response curve obtained by measuring the response to a signal of fixed frequency, when the tuning condenser is varied, is the same as the curve obtained by measuring the response of the circuit (with fixed tuning) to signals of varying frequency, provided that we are only concerned with small changes in capacity and frequency. In the case just discussed, the frequency variation of 10,000 cycles, *i.e.*, the band width, is small in comparison with the carrier frequency of 1,000,000 cycles, a mere 1 per cent. of it, in fact.

Types of Curves obtained with different Circuit Constants

The curve of Fig. 2 is unattainable in practice with a single tuned circuit. Fig. 3 shows two types of curve that may be obtained by different choice of circuit constants, *i.e.*, by different choice of coil and condenser values. Curve (*a*) is that obtained with a coil of poor efficiency, *i.e.*, a coil possessing a large amount of resistance, and curve (*b*) is the response of a highly efficient circuit. It is clear that if we employ a highly selective circuit, such as that represented by (*b*), the response to the waves at the extreme ends of the band is poor.

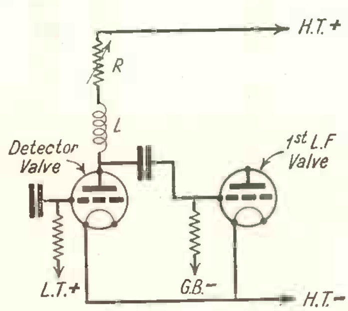


Fig. 6.—A Series Circuit, comprising a Resistance and an Inductance, acts as a Corrective Filter.

In other words, the higher audio frequencies are attenuated — the high notes are lost, or partly lost. On the other hand, if we employ a circuit which does not distort the modulation, the response extends over a much wider band than the actual band width of the station we are endeavouring to receive, and interference is experienced. We must compromise between high note loss and interference. (A recent development in reception technique, known as "Tone Correction," offers a better remedy with which we shall deal later.)

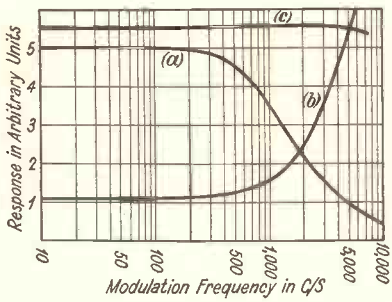


Fig. 7.—CURVES SHOWING HOW THE CORRECTIVE CIRCUIT OF FIG. 6 COMPENSATES FOR HIGH NOTE LOSS.

ploying a circuit with an inefficient coil, or by employing a large inductance and a small capacity to tune to the desired wavelength. A curve similar to (*b*) is obtained by employing an efficient coil—a coil wound with, say, Litzendraht wire—or by employing a coil of small inductance tuned by a condenser of large capacity. That is to say, for coils of equal efficiency, the degree of selectivity and the extent of the high note attenuation depend on the ratio of inductance to capacity employed in the circuit. A small L to C ratio gives selectivity, and a large L to C ratio gives unselective reception and uniform response to side-band waves. These are the prime essential facts for designing single tuned circuits.

Cascade Connection

The use of two circuits in a receiver accentuates the overall selectivity—not two closely coupled circuits but two single circuits coupled through a valve in the conventional manner. Fig. 4 shows the effect, on the overall response, of employing two single circuits connected in this way—the engineer uses the term "connected IN CASCADE." Curve (*a*) is the response of each circuit separately, and (*b*) is that of the two together. Greater selectivity is obtained at the expense of a certain amount of high note loss.

Band Width of a Response Curve

The band width of a response curve is not very clearly defined, especially when the sides of the curve slope considerably: it is usual to take the band width as the width across the response curve where the response is 0·7 times the response at the peak of the curve, as shown at Fig. 5. Actually the figure taken is 0·707, but the previous figure is sufficiently near this for most practical work.

In the case of Fig. 3, a response curve similar to (*a*) can be obtained by em-

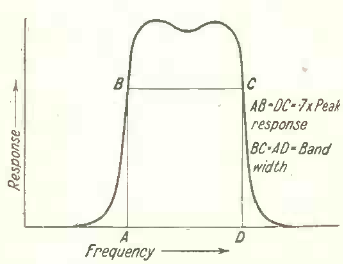


Fig. 8.—RESPONSE OF A TYPICAL BAND-PASS CIRCUIT, COMPRISING TWO COUPLED TUNED CIRCUITS.

Tone Correction

The practice of "tone correction" applied to radio receivers is of comparatively recent date, but tone correction, under the name "line correction," has been known to telephone engineers for many years.

We have seen that if highly selective single tuned circuits are employed in a receiver the higher modulation frequencies are considerably attenuated. The object of tone correction is automatically to compensate for the attenuation by employing, in the post detector stages of the receiver (and therefore in the post tuned-stages) filters which emphasise the higher notes relative to the bass notes. By correct choice of the values of the circuit components, exact compensation can be obtained.

How a Series Circuit acts as a Corrective Filter

It can be shown that a series circuit comprising a resistance and an inductance acts as a

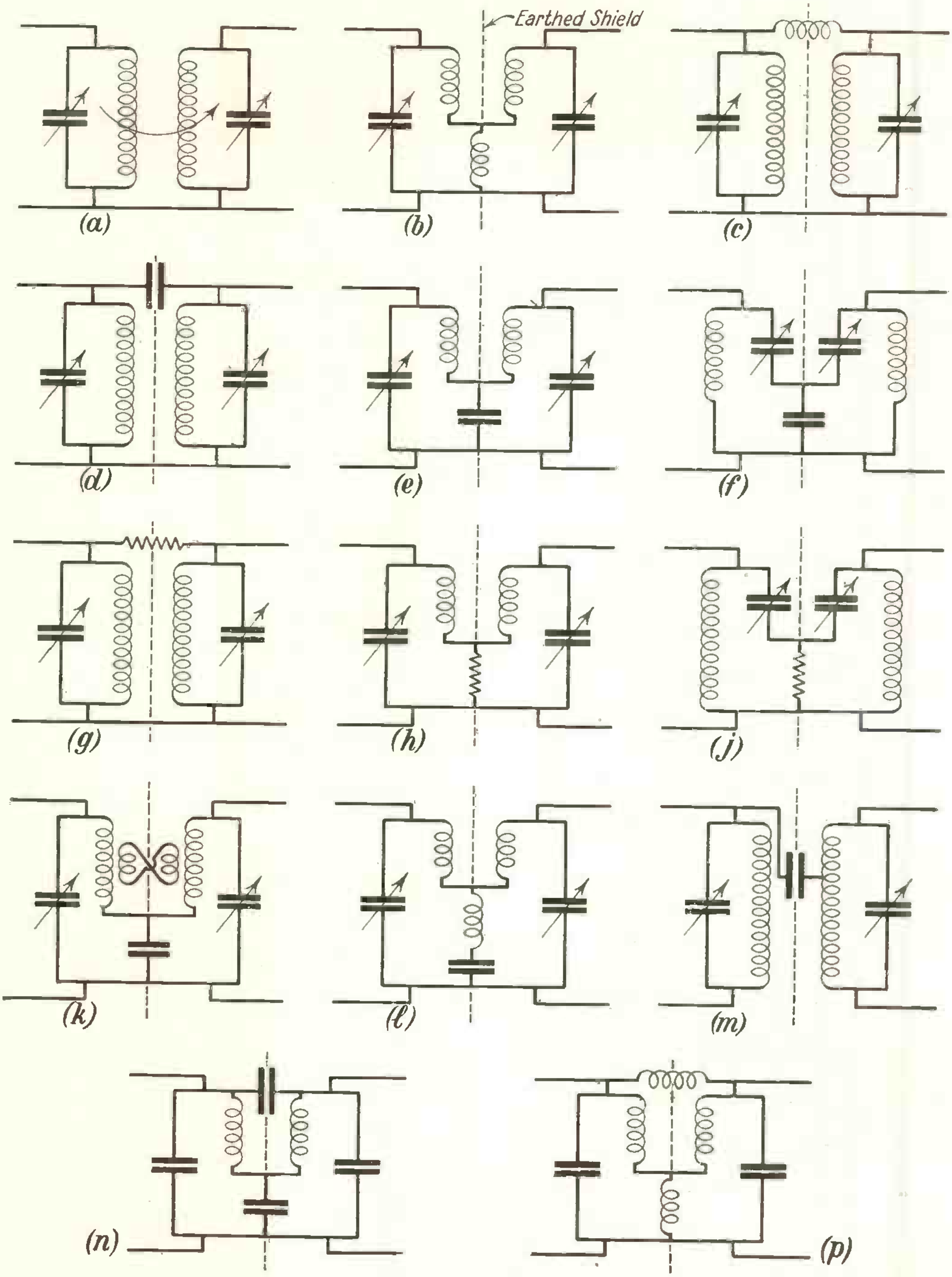


Fig. 9.—Several Different Forms of Coupling.

(a)—(c), Inductive coupling; (d)—(f), Capacitative coupling; (g)—(j), Resistive coupling; (k)—(p), Mixed coupling, *i.e.*, combinations of either the previous three types of coupling or the various arrangements of any one type.

corrective filter to the distortion in the response of a single tuned circuit, and such a device forms part of the post detector circuit in a tone controlled receiver, as shown in Fig. 6. The curves of Fig. 7 show how the corrective circuit compensates for the high note loss: (*a*) represents the tuned circuit response, and (*b*) the response of the filter circuit. Curve (*a*) multiplied by curve (*b*) gives the overall response which is shown by curve (*c*), and which is seen to be practically level over the audible range considered.

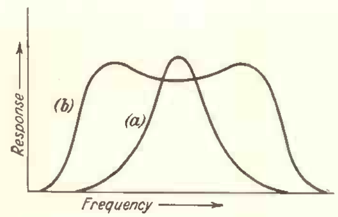


Fig. 10. — Response Curves obtained by (*a*) too Weak Coupling, and (*b*) too Tight Coupling.

Overhearing

The use of highly selective tone controlled receivers aids considerably in the reduction of one form of inter-station interference, viz., that which is due to the direct detection of the unwanted signal. This form of interference is sometimes called Overhearing by engineers: it is "intelligible" interference, *i.e.*, the audio output due to it is the intelligible speech or music radiated by the unwanted station. The other form of interference is "non-intelligible" and is due to the combinations of the wanted and unwanted stations' signals by the detector stage, or even by pre-detector stages. This latter form cannot be eliminated by "tone correction" except by introducing a certain degree of audio distortion.

COUPLED CIRCUITS

The theory of closely coupled circuits is somewhat complex, but their behaviour is sufficiently described, for our present purpose, by their response curves. Circuit analysis shows that when two tuned circuits are directly coupled together, either by reactive or resistive means, *and when they are both tuned to the same frequency*, the overall response curve shows two "humps," or "peaks," instead of the single peak of Figs. 3, 4 and 5. The peaks occur on each side of the frequency to which both circuits are tuned. Fig. 8 shows the response of a typical band-pass circuit comprising two coupled, tuned circuits. The shape of the curve varies with the frequency to which the device is tuned, and depends, also, on the degree of coupling existing between the two elements of the filter.

Different Forms of Coupling

Fig. 9 shows several different forms of coupling, all of which may be employed with great success by correct choice of values of the components concerned. It is found, however, that a reasonably consistent response is not obtained over a wide wave range when the coupling employed comprises only a single coil or condenser. The reason for this is that the impedance of a single coil or condenser varies with frequency, and hence the value of the coupling impedance varies with frequency.

Resistive Coupling

When a "mixed" coupling or a resistive coupling is employed the impedance remains sensibly constant over the tuning range, provided, of course, that in the former case, the correct "mixture" of coupling elements be employed. Filters with "mixed" couplings are also shown in Fig. 9. Strictly speaking, the term "mixed" should only be applied to cases where the coupling is partly inductive and partly capacitative, but it is used here to denote coupling by more than one common element whether the common elements be the same or different.

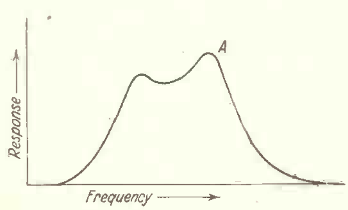


Fig. 11.—If an Assymmetrical Curve is obtained it indicates that some part of the Circuit is Incorrectly Adjusted.

Response Curves for Various Conditions

In Fig. 10 are shown the response curves obtained by (*a*) too weak coupling between the two tuned circuits, and (*b*) too tight coupling. The symptoms are: for (*a*), hyperselectivity and considerable high note loss, and for (*b*), poor selectivity and good tonal quality. These symptoms are clear from an inspection of the curves, for we have seen that a steep-sided curve, enclosing a narrow frequency band, has the characteristics attributed to (*a*), and a curve including a wide frequency band has those attributed to (*b*). By judicious adjustment of the degree of coupling, a band-pass filter can be made highly selective and yet to respond to signals over a reasonably wide frequency range. This is seen to be the case in Fig. 8, where the band width is clearly defined.

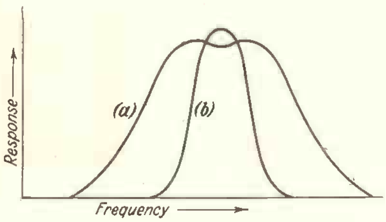


Fig. 12.—Two Response Curves. (*a*) A band-pass filter; (*b*) a single tuned circuit.

Causes of an Assymmetrical Response Curve

If an assymmetrical response curve, *i.e.*, a curve which is *not* symmetrical, is obtained, as shown in Fig. 11, either the two coils are not sufficiently well matched to each other, or else the tuning is at fault. In the latter case, adjustment of one of the trimmer condensers on the gang assembly may cure the fault. Such an assymmetrical curve may be detected by observing how far audibility extends on each side of the tuning position of a station: uneven audibility ranges indicate lack of response curve symmetry. It may also be detected by observing whether a marked peak is obtained (as at A in Fig. 11) on one side of the tuning position of a station.

Combined Curve of a Band-Pass Filter and a Single tuned Circuit

In Fig. 12 are shown the response curves of (*a*) a band-pass filter, and (*b*) a single tuned circuit. If we employ these two circuits and couple them through a valve, as shown in Fig. 13, we shall obtain the overall response curve of Fig. 14, which is the *product* of the two curves of Fig. 12. Comparing this curve with Fig. 2, we see that the combination approaches very closely to the ideal.

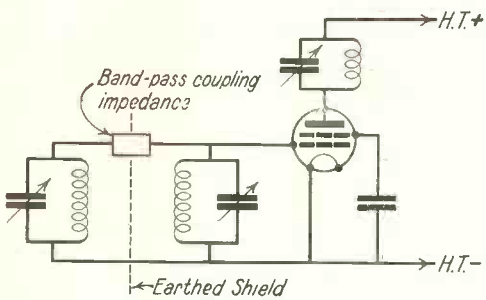


Fig. 13.—The Two Circuits coupled through a Valve.

Tone Correction with Band-pass Filters

The theory of tone correction as applied to receivers employing single tuned circuits also applies to instruments incorporating band-pass filters. In this case, however, the tone correction device requires slight modification in order that exact compensation may be obtained, for the curvature of the sides of the band-pass filter response curve, which is responsible for the high note loss, is different from that of the response curve of a single tuned circuit.

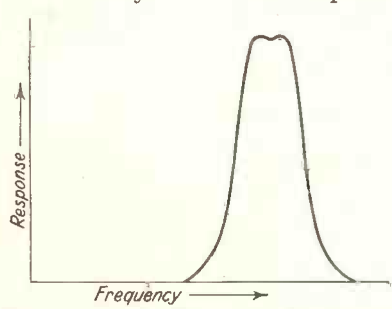


Fig. 14.—The Overall Response Curve due to (*a*) and (*b*) of Fig. 12.

Interference resulting from Unselective Reception

We have so far discussed the question of selectivity from the point of view of the response curve of the receiver and of the tuning circuits. Let us now consider, briefly, the interference resulting from unselective reception. In Fig. 15 are shown, diagrammatically, the band widths of two stations with carrier frequencies of f_1 and f_2; the three curves, (*a*), (*b*), and (*c*) are typical response curves of tuned circuits. The response shown by (*a*) is unselective, and it is clear that signals from both stations will be present in the receiver: only some of the side-band waves of the second station will be present, however, and the carrier wave of this station is absent from the total response. When this complex signal reaches the detector valve a combination process ensues and new tones are introduced into the modulations of both stations' signals.

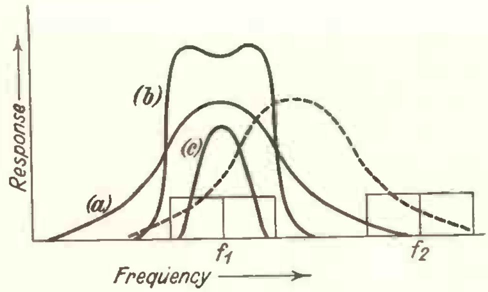


Fig. 15.—Diagrammatic Representation of the Band Widths of Two Stations with Different Carrier Frequencies.

Output from Detector

The output from the detector, which is ultimately fed to the loud-speaker, contains :—

(1) The modulation of the first station;
(2) some of the modulation of the second station; and
(3) other unintelligible sounds which are mixtures of the modulations of the two stations.

Interference Bands

Because the carrier wave of the second station is not included in the response curve there will be no heterodyne whistle in the output. If we displace the response curve slightly to the right, as shown by the dotted curve, the carrier wave f_2 is included, and the steady heterodyne whistle is present amongst the interference tones. Most readers are familiar with the nature and occurrence of these INTERFERENCE BANDS, as they are often called.

Side-band Cutting

In the case of the response shown by curve (*b*) only the signal from the first station is heard. If the response curve be shifted slightly to the right (*i.e.*, if we re-adjust the tuning of the circuit) signals from both stations will be received, and the output will include the interference bands just noted.

The response (*c*) is so highly selective that the higher modulation frequencies are lost. This is known as side-band cutting.

Minimum Frequency Difference to prevent Overlapping

Now suppose that the carrier frequency, f_2, of the second station is changed so that the two bands overlap. In this case interference bands will always be present in the output unless we employ a circuit with a response similar to (*c*), in which case we can eliminate the interference, but only at the expense of tonal quality. The minimum frequency difference between the carrier frequencies of two stations so that overlapping does not occur depends, of course, on the highest audio frequencies present in the modulation. Suppose that each station transmits audio frequencies up to 5,000 cycles, but none higher, then the difference between f_1 and f_2 must be 10,000 cycles, *i.e.*, 10 kilocycles. If the frequency separation is less than 10 kilocycles the bands overlap, and if more, they are quite distinct.

Interference Bands in Superheterodynes

The case of interference bands in superheterodyne receivers requires special treatment. Here is a summary of the results of an analysis made by the present writer in a paper to be published shortly. Interference takes the form of :—

(1) Interference bands of the same nature as those experienced with ordinary single detector receivers, and due to the combinations of the modulations of the wanted and unwanted stations; and
(2) whistling tones whose pitch varies slightly when adjustments are made to the tuning control.

TESTED CIRCUITS

By E. W. HOBBS

In the following pages we give twelve tested circuits, together with a list of suitable components and layout. Each one of these circuits has been specially built up and tested, approximate dial settings of some of the stations received at good strength are given.

A STRAIGHT TWO

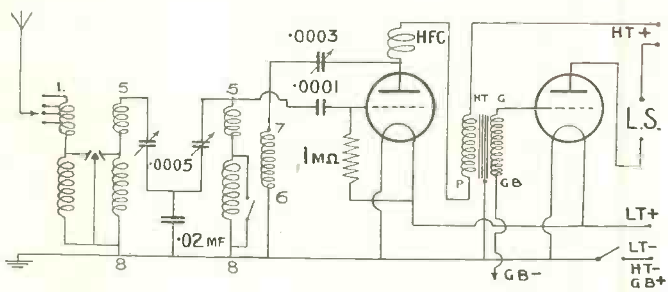


Fig. 1.—Circuit of the Straight Two.

AN inexpensive receiver giving choice of half a dozen alternative programmes at entertainment strength on the loud speaker, and practically the whole of Europe on headphones.

SELECTED COMPONENTS

The following components were used in the test set and are confidently recommended :—

Tuner.—Combined condenser and coil assembly with dual coils and matched ganged condensers on aluminium base. *No.* 68c. (" *Formo.*")

Reaction Condenser. — ·0003 mfd., with slow-motion knob (" *Polar* ").

H.F. Choke.—" Midget " type (" *Telsen* ").

L. F. Transformer.—" Ace " Ratio 5–1 (" *Telsen* ").

Valve Holders.—2 Rigid Type (" *Telsen* ").

Fixed Condensers.—1 ·0001 mfd. with G.L. clips (" *T.C.C.*") ; 1 ·02 mfd. non-inductive (" *T.C.C.*").

Grid Leak.—1 megohm (" *Lissen* ").

Switch.—1 " On-off " Q.M.B. (" *Bulgin* ").

Loud Speaker.—PM5 Permanent Magnet Moving Coil (" *Rola* ").

Batteries.—H.T. 120-volts Type H1012 (" *Drydex* ") ; L.T. Gel-Cel JWF7 (" *Exide* ") ; Grid Bias, Type H1040 (" *Drydex* ").

Valves.—Detector, HL210 (" *Osram* "); Power, P220A (" *Mazda* ").

Terminals.—1 each marked A and E ; 4 wander plugs ; 2 Battery Tags ; 1 Wanderfuse (" *Belling Lee* ").

TEST DIAL SETTINGS

Trieste	9	Beromunster	76
London National	20	North Regional	80
Scottish National	23	Prague	82
Hilversum	26	Brussels	90
Poste Parisien	32	Radio Paris	75
London Regional	39	Zeesen	68
Midland Regional	52	Daventry	60
Rome	71	Kalundborg	32

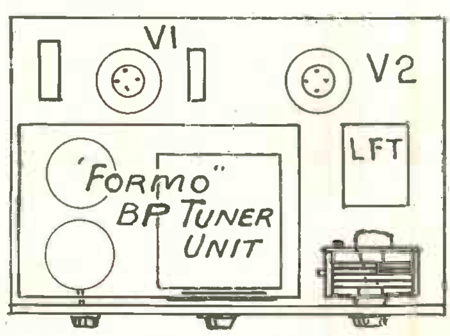


Fig. 1a.—Layout of Components.

THE PENTODE TWO

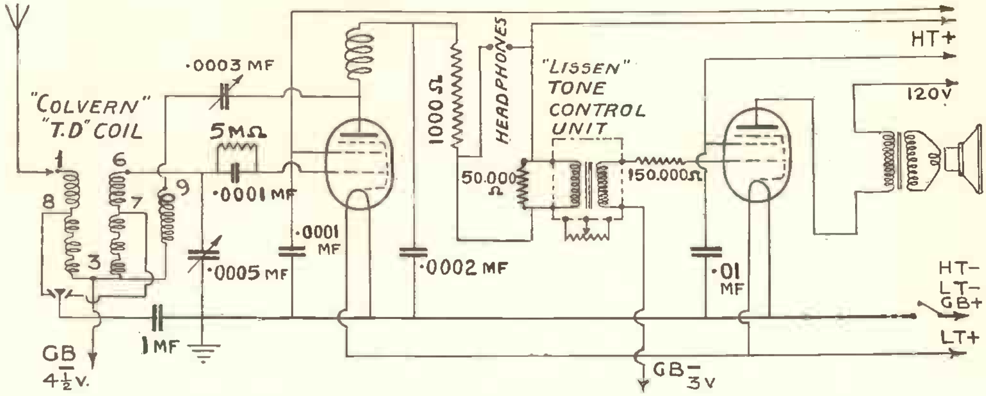


Fig. 2.—CIRCUIT OF PENTODE TWO RECEIVER.

SPECIAL FEATURES

In this novel but practical circuit the peculiar sensitivity of " Mazda " Pentode Valves to weak input signals is utilised in an ingenious manner. The Colvern T.D. coil has a variable aerial coupling; when plugged into socket No. 1, this gives maximum selectivity and lowest signal input, but quite enough for the purpose.

COMPONENTS REQUIRED

COIL.—Colvern Dual Range Type T.D.

TUNING CONDENSER.—Universal Precision ·0005 mfd. (" *Jackson Bros.*").

SLOW MOTION DIAL.—Bronze Illuminated (" *Jackson Bros.*").

REACTION CONDENSER.—" Tiny " ·0003 mfd. (" *Jackson Bros.*").

H.F. CHOKE.—Lewcos " Midget " H.F.

WAVE CHANGE SWITCH.—3 point.

ON-OFF SWITCH.—G22 (" *Wearite* ").

L.F. TRANSFORMER.—" Hypernik " 3 to 1 (" *Lissen* ").

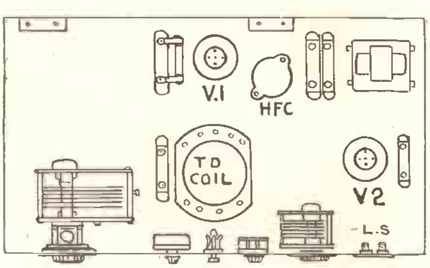


Fig. 2A.—LAYOUT OF COMPONENTS.

TONE CONTROL.—Tone Control Unit with Potentiometer (" *Lissen* ").

FIXED CONDENSERS.—2 ·0001 mfd., 1 ·01 mfd., 1 ·0002 mfd. (" *T.C.C.*") ; 1 1 mfd. non-inductive (" *T.C.C.*").

RESISTANCES.—1 1,000-ohms Spaghetti (" *Lewcos* ") ; 1 50,000-ohms " *Erie* " ; 1 150,000-ohms metallised (" *Dubilier* ").

GRID LEAK.—1, 5 megohm (" *Graham Farish* ").

VALVE HOLDERS.—2 (" *Godwinex* ").

VALVES.—2, Pen. 220 (" *Mazda* ").

BATTERIES.—1 L.T. 2-volt Gel-Cel JWF. 7 (" *Exide* ") ; 1 G.B., H1002 Drydex (" *Exide* ") ; 1 H.T. 120-volt No. H1012 Drydex (" *Exide* ").

LOUD SPEAKER.—M. 3 T. (" *Ferranti* ").

TERMINALS.—1 twin-socket strip " Loud Speaker " ; 1 ditto aerial earth ; 1 ditto headphones ; 2 battery tags (" *Belling-Lee* ").

WANDERPLUGS.—1 G.B.+, 2 G.B.−, 4 HT+ (" *Belling Lee* ").

FUSE.—1 " Wanderfuse " 150 milliampere (" *Belling Lee* ").

BASEBOARD.—14 by 8 by ⅜ inches.

AERIAL.—30 feet " Plastape " (" *Kenden Manufacturing Co.*").

TEST DIAL SETTINGS

London National	38	North Regional	85
North National .	50	Beromunster	86
London Regional	63	Prague .	90
Scottish Regional	68	Daventry .	68
Toulouse . .	72	Zeesen . .	72
Athlone . .	80	Radio Paris .	81

THREE VALVE WITH OPTIONAL SWITCHING

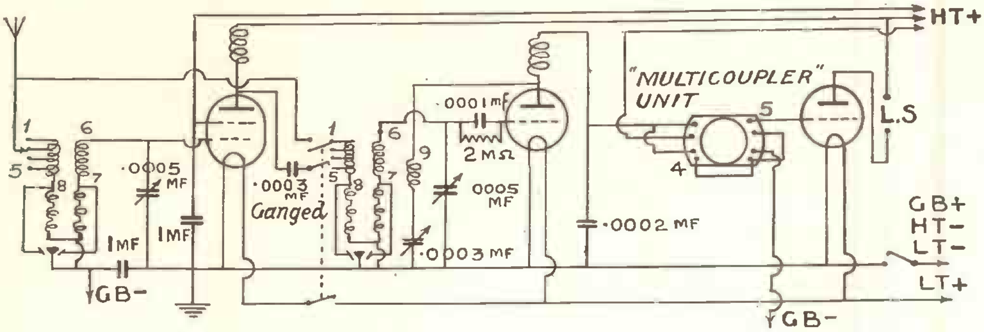


Fig. 3.—CIRCUIT OF THREE-VALVE RECEIVER WITH OPTIONAL SWITCHING.

SPECIAL FEATURES

Optional switching, providing a straight 2-valve selective circuit for local station reception on long or medium waves. Alternatively a 3-valve S.G. circuit—very sensitive and selective—for reception of distant stations. Variable selectivity is obtained by inserting aerial lead into terminals 1, 2, 4, 5, the latter giving greatest selectivity. Ganged tuning and wave change. Correct aerial coupling is maintained by automatically switching into circuit an aerial loading coil when the L.W. winding is switched into circuit.

COMPONENTS REQUIRED

TUNING CONDENSER. — Dual ganged ·0005 " Nugang " (" *Jackson Bros.*") ; Illuminated S.M. Dial (" *Jackson Bros.*") ; ·0003 " Tiny " Reaction Condenser (" *Jackson Bros.*").

COILS.—2 Type " T. D." (" *Colvern* ").

WAVE CHANGE SWITCH.—2 Type S2 ganged (" *Colvern* ").

CHOKES.—1 HFP, 1 HFPA, H.F. Chokes (" *Wearite* ").

FIXED CONDENSERS.—2 1 mfd. ; 2 ·0003 mfd. ; 1 ·0002 mfd. (" *T.C.C.*").

TRANSFORMER. — 1 " Multicoupler " (" *Formo* ").

GRID LEAK.—1 2 megohm (" *Dubilier* ").

SWITCH. — 1 " On - Off " No. G22 (" *Wearite* ") ; 1 3-Way No. L23 (" *Wearite* ").

VALVE HOLDERS.—3 4-pin (" *Telsen* ").

WIRING.—2 coils " Glazite," 3 yards " Lewcoflex " (" *Lewcos* ").

BASEBOARD.—Plywood, 14 by 8 by ⅜ inches.

BATTERIES.—1 H1012 " Drydex " ; 1 H1001 " Drydex," 1 JWF7 Gel-Cel (" *Exide.*").

SPEAKER. — 1 P.M., M.C., Type D9 (" *Igranic* ").

TERMINALS.—2 Battery Tags, 2 Twin Socket Strips, 7 Wanderplugs (" *Belling Lee* ").

FUSE.—1 " Scrufuse " 150 milliampere and Base (" *Belling Lee* ").

VALVES.—1 SG215 Met ; 1 L2, 1 P220A (" *Mazda* ").

AERIAL.—30-foot " Plastape " Indoor (" *Kenden Manufacturing Co* ").

TEST DIAL SETTINGS

Fecamp	16	London Regional	67
Trieste	22	Stockholm	128
London National	30	Prague	152
Heilsberg	46	Daventry	122
North National	55	Radio Paris	148
Breslau	59		

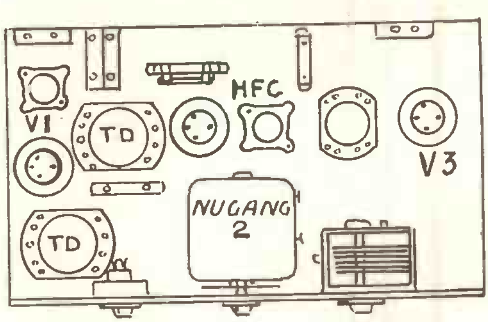


Fig. 3A.—LAYOUT OF COMPONENTS.

A SCREEN-GRID FOUR

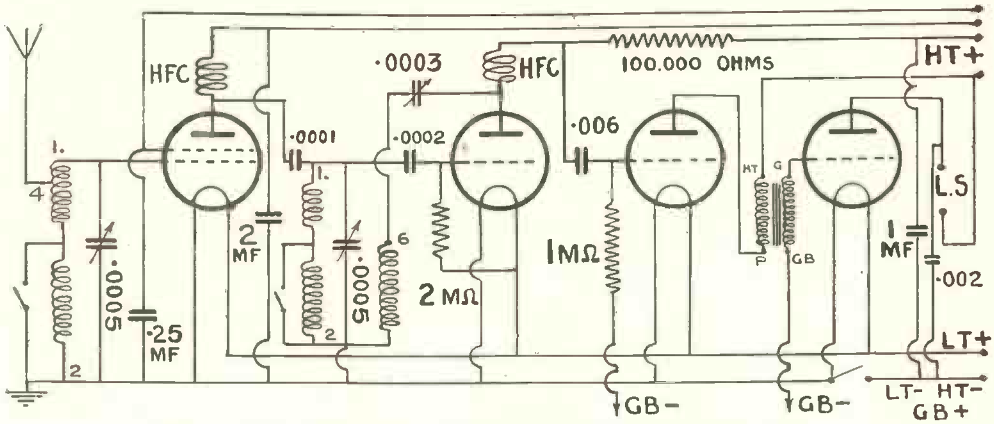


Fig. 4.—The Theoretical Circuit of the Screen-grid Four.

SELECTED COMPONENTS

An ideal receiver for country districts, thirty miles or more from a broadcasting station. Two tuned circuits give adequate selectivity while retaining full tonal qualities :—

Coils.—2 Type ATG/R Dual Range (" *Lewcos* ").

Tuning Condenser.—Dual " Nugang " ·0005 mfd. (" *Jackson* ").

Reaction Condenser.—" Precision " ·0003 with slow-motion knob (" *Jackson* ").

H.F. Chokes.—1 " Midget " (" *Lewcos* ") ; 1 " Super H.F." (" *Lewcos* ").

Loud Speaker.—P.M. Moving Coil Type M3T (" *Ferranti* ").

Batteries.—H.T. 120-volts Type H1012 ; G.B. Type H1002 (" *Drydex* ") ; L.T. Gel-Cel Type JZ4 (" *Exide* ").

Valves.—H.F. 1 No. SG215 metallised (" *Mazda* ") ; Det. 1 No. HL210 metallised (" *Mazda* ") ; L.F. 1 No. PMIHL ; Power 1 No. PM202 (" *Mullard* ").

Transformer.—1 No. AF10 ("*Ferranti*").

Valve Holders.—4 4-pin. ("*Lissen*").

Fixed Condensers.—1 ·0001 ; 1 ·0002 with G.L. clips ; 1 ·25 mfd. ; 1 1·0 mfd. ; 1 2·0 mfd. ; 1 ·006 mfd. ; 1 ·002 mfd. all non-inductive (" *T.C.C.*").

Resistances.—1 2 meg. ; 1 1 meg. (" *Graham Farish* ") ; 1 100,000-ohms Spaghetti (" *Lewcos* ").

Switch.—1 " On-off " (" *Telsen* ").

Sundries.—Battery Cord, 6-way with " Wanderfuse " (*Belling Lee* ") ; 1 Battery Connector (" *Bulgin* ") ; 2 L.T. Battery Tags (" *Belling Lee* ").

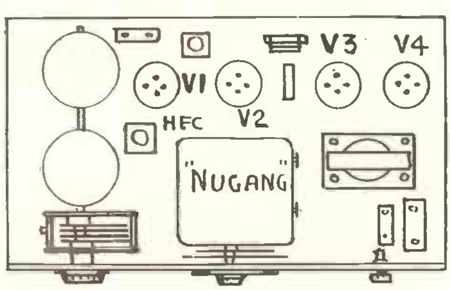


Fig. 4a.—Layout of Components.

TEST DIAL SETTINGS

Medium Wave

Trieste	22
London National	27
Hilversum	52
North National	57
Poste Parisien	69
London Regional	84
Lwow	99
Midland Regional	109
Sottens	114
Rome	128
Beromunster	138
North Regional	147
Prague	152
Brussels	161
Vienna	166
Budapest	176

Long Wave

Radio Paris	148
Zeesen	135
Daventry	122
Motala	88
Kalundborg	53
Oslo	42

FOUR-VALVE SET WITH BAND-PASS TUNING

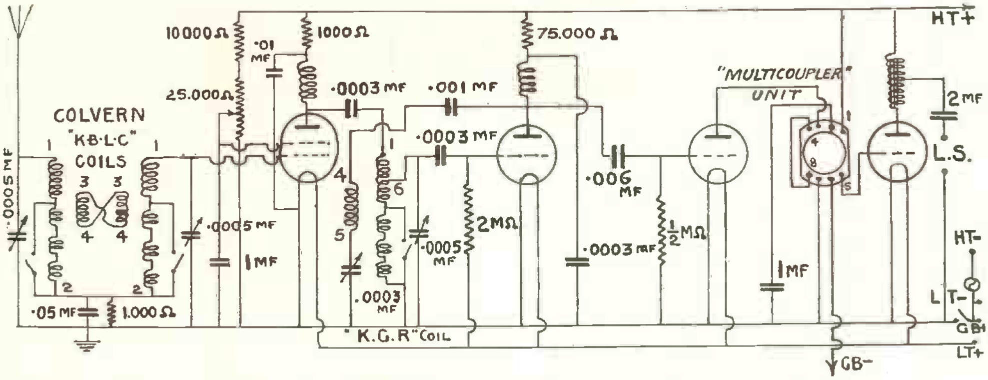


Fig. 5.—Circuit for Four-Valve Receiver with Band-Pass Tuning.

SPECIAL FEATURES

Selectivity, great range and excellent tonal qualities characterise this straightforward receiver. Controls are a minimum, one knob controls all three tuned circuits, a combined volume control and on-off switch is provided, also reaction control. Ganged wave change switches are incorporated in the Colvern coils.

COMPONENTS REQUIRED

Coils.—2 KBLC, 1 KGR on chassis with ganged wave change switching (" *Colvern* ").

Tuning Condenser.—Triple gang ·0005 mfd. " Nugang," with slow motion drive (" *Jackson Bros.*").

Reaction Condenser.—·0003 " Tiny " with slow motion knob and dial ("*Jackson Bros.*").

Volume Control.—25,000-ohms Q.V.C. with QMB switch ganged (" *Wearite* ").

H.F. Chokes.—1 Type HFP, 1 HFPA (" *Wearite* ").

L.F. Transformer.—" Multicoupler " (" *Formo* ").

R.C. Unit.—1 Type R.C. with valve holder (" *Dubilier* ").

Valve Holders.—3 4-pin ("*Godwinex.*")

Fixed Condensers.—1 ·05 mfd., 1 ·001 mfd., 1 ·0005 mfd., 1 ·0001 mfd., 2 1 mfd., 2 2 mfd. (" *T.C.C.*").

Resistances.—2 megohm (" *Dubilier* ") 2 1,000-ohms Spaghetti (" *Lewcos* ").

L.F. Choke.—1 Type L.F.C. centre tapped (" *Lewcos* ").

Valves.—1 S215, 1 HL2 metallised 1, L2; 1, P220 (" *Mazda* ").

Batteries.—1 2-volt Gel-Cel, JWF7 (" *Exide* ") ; 1 G.B., No. 1002 (" *Exide* ").

Mains Unit.—Type AK260 " Atlas " with trickle charger (" *Clarke & Co., Ltd.*").

Loud Speaker.—P.M., Type F.7 (" *Rola* ").

Terminals.—Wander plugs, 2 G.B.— 1 G.B. + ; 2 battery tags ; 2 twin socket strips (" *Belling Lee* ").

Wiring.—2 coils " Glazite," 3 yards " Lewcoflex " (" *Lewcos* ").

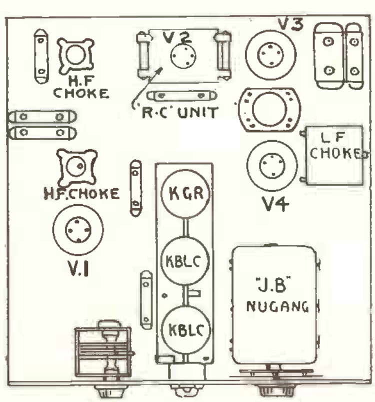


Fig. 5A.—Layout of Components.

TEST DIAL SETTINGS

Medium Wave

Fecamp	11
London Nat.	19
Genoa	34
London Reg.	50
Athlone	62
Beromunster	76
Vienna	95

Long Wave

Radio Paris	56
Daventry	49
Eiffel Tower	30

VARIABLE MU Q.P.P. FOUR-VALVE SET

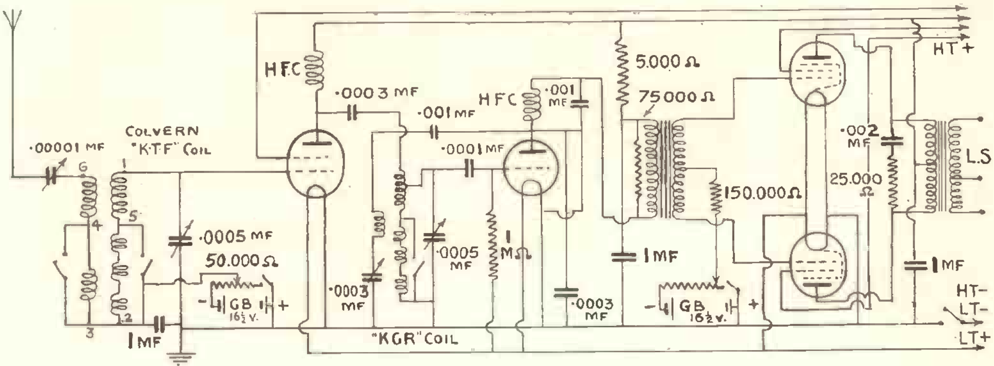


Fig. 6.—VARIABLE MU Q.P.P. FOUR-VALVE CIRCUIT.

SPECIAL FEATURES

A good all-round serviceable receiver, gives ample selection of alternative programmes, and enormous volume on local and powerful transmissions.

A "Ferranti" multiratio output transformer enables any existing loud speaker to be matched and used.

COMPONENTS REQUIRED

COILS.—1 Type K.T.F., 1 Type K.G.R. ("*Colvern*").

TUNING CONDENSER.—"Nugang" dual ·0005 mfd. with slow-motion knob and dial ("*Jackson Bros*").

REACTION CONDENSER.—·0003 "Universal," with slow-motion knob and dial ("*Jackson Bros.*").

H.F. CHOKES.—1 Type HFPA, 1 Type HFP ("*Wearite*").

AERIAL CONDENSER.—1 "Neutralising" ("*Jackson Bros.*").

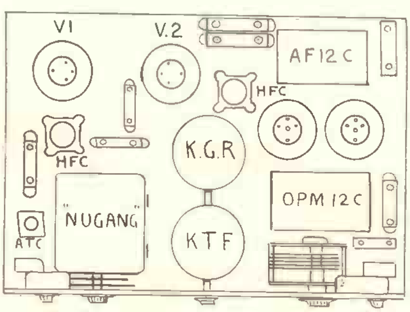


Fig. 6A.—LAYOUT OF COMPONENTS.

L.F. TRANSFORMERS.—1 Type AF12C, 1 Type OPM12C output; both for Q.P.P. operation ("*Ferranti*").

FIXED CONDENSERS.—1 ·002 mfd., 2 1 mfd., 400 V.D.C. working ("*T.C.C.*"); 2 ·001 mfd., 2 ·0003 mfd. ("*T.C.C.*").

FIXED RESISTANCES.—1 1 megohm, 1 5,000 ohms, 1 75,000 ohms, 1 25,000 ohms, 1 150,000 ohms, all 1 watt metallised ("*Dubilier*").

POTENTIOMETER. — 1 50,000 ohms, 1 25,000 ohms wire wound, Type Q.V.C., each with ganged on-off switch ("*Wearite*").

SWITCH.—1 2-way "on-off."

VALVES.—1 No. S215, V.M. ("*Mazda*") 1 No. HL2, metallised ("*Mazda*"); 2 No. P220A, Pentodes ("*Mazda*").

VALVE HOLDERS.—2 4-pin, 2 5-pin.

BATTERIES.—1 Drydex special Q.P.P. type, No. 1060 ("*Exide*"); 2 16½-volt G.B., No. 1002 ("*Exide*"); 1 2-volt accumulator ("*Exide*").

BASEBOARD.—14 by 10 by ⅜ inches, covered with "Konductite" ("*C.A.C. Cabinets, Ltd.*").

TEST DIAL SETTINGS

Fecamp	10	Beromunster	74
London National	18	North Regional	84
Genoa	33	Vienna	93
Post Parisien	38	Munich	98
London Regional	50	Huizen	60
Athlone	62	Radio Paris	56
Stockholm	70	Daventry	48

FIVE-VALVE BATTERY RECEIVER

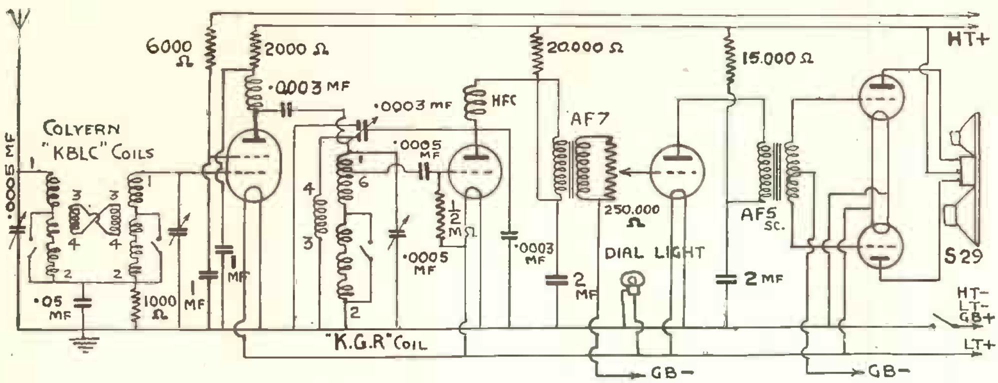


Fig. 7.—CIRCUIT OF FIVE-VALVE BATTERY RECEIVER.

SPECIAL FEATURES

High selectivity, adequate range and maximum power from a battery operated set are features of this receiver.

COMPONENTS REQUIRED

COILS.—2 K.B.L.C.; 1 K.G.R. ganged on chassis (" *Colvern.*").

TUNING CONDENSER.—Triple gang ·0005 " Nugang " with drum dial drive (" *Jackson Bros.*").

REACTION CONDENSER.—1 ·0003 Differential with knob and dial (" *Jackson* ").

FIXED CONDENSERS.—3 2 mfd., 400 V.D.C. working, 2 1 mfd. (" *T.C.C.*"); 1 ·05 mfd. non-inductive (" *T.C.C.*"); 2 ·0003 mfd., 1 ·0005 mfd. (" *T.C.C.*").

FIXED RESISTANCES.—1 6,000 ohms; 1 20,000 ohms (" *Dubilier* "); 1 15,000 ohms metallised (" *Dubilier* "); 1 2,000 ohms strip wire wound (" *Igranic* ").

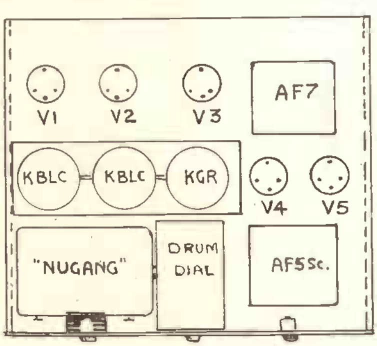


Fig. 7A.—LAYOUT OF COMPONENTS.

GRID — LEAKS. — 1 ½ megohm (" *Igranic* ").

SWITCH.—" On-Off " 922 (" *Wearite* ").

H.F. CHOKE.—1 Type HFP, 1 Type HFPA (" *Wearite* ").

VALVES.—1 S215A metallised, 1 HL210, 1 L2, 2 P220 (" *Mazda* ").

VALVE HOLDERS.—4 4-pin; 1 5-pin chassis mounting type (" *Bulgin* ").

L.F. TRANSFORMERS.—1 Type AF7; 1 Push-pull type AF5c (" *Ferranti* ").

LOUD SPEAKER.—Celestion Reetone S.29 (" *Celestion Ltd.*").

POTENTIOMETER.—1 250,000 ohms wire wound (" *Lewcos* ").

BATTERIES.—2 No. H1015 Triple Capacity Drydex (" *Exide* "); 1 G.B. No. H1037 Drydex (" *Exide* "); 2-volt L.T. accumulator, No. HZ4 (" *Exide* ").

BASEBOARD.—13 by 11 by ½ inches, covered Konductite on both sides and provided with battens 2 inches deep and ¾ inch thick at each end (" *C. A. C. Cabinets* ").

TERMINALS.—15 " R " type, 3 Wander-plugs, 1 Wanderfuse, 1 twin socket strip (" *Belling Lee* ").

TEST DIAL SETTINGS

A few specimens for calibration purposes :—

Trieste . .	15	Prague. .	78
London National	19	Brussels, No. 1	84
Heilsberg . .	22	Huizen .	88
Genoa . .	29	Radio Paris .	75
London Regional	40	Daventry .	59
Midland Regional	52	Eiffel Tower.	50

Q.P.P. AMPLIFIER

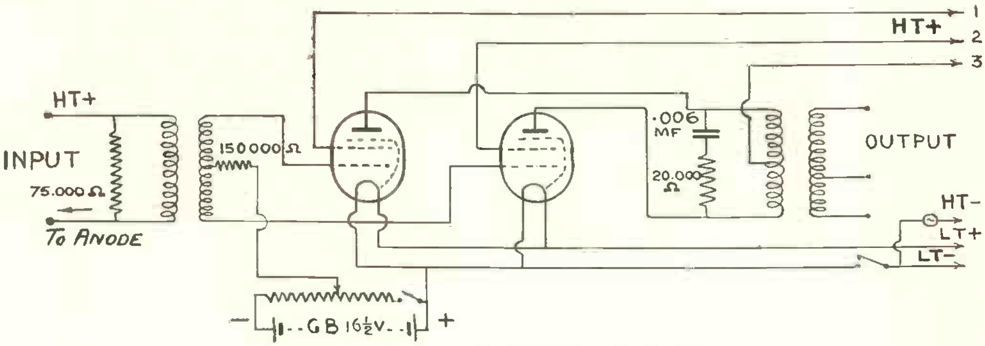


Fig. 8.—Circuit for Q.P.P. Amplifier.

SPECIAL FEATURES

This two-valve amplifier is intended to follow any battery set and adds enormously to its power output.

The Pentode valves should be adjusted so that the quiescent current does not exceed 3½ m.a. for the two. A special "Drydex" Q.P.P. battery is recommended for use with the amplifier, as this battery is specially prepared for Q.P.P. work and has the requisite voltage tappings.

COMPONENTS REQUIRED

Transformers.—1 No. AF12C Audio Transformer (" *Ferranti* "); 1, No. OPM12C Output Transformer (" *Ferranti* ").

Valves.—2 Pen. 220A (" *Mazda* ").

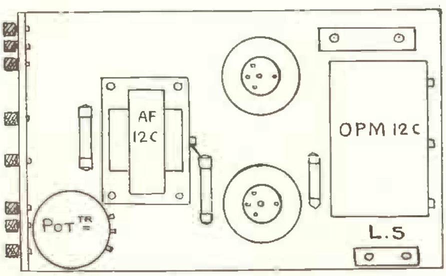


Fig. 8a.—Layout of Components.

Valve Holders.—2 5-pin(" *Wearite* ").

Fixed Condenser.—1 ·006 mfd. (" *T.C.C.* ").

Resistances.—1 20,000 ohm, 1 50,000 ohm, 1 150,000 ohm, all 1 watt, metallised (" *Dubilier* ").

Potentiometer.—1 50,000 ohm with ganged switch (" *Wearite* ").

Baseboard.—Plywood, 10½ by 6½ by ⅜ inches.

Terminals.—6 " R " Type, with indications, H.T. + 1; H.T. + 2; H.T. + 3; G.B.—, L.T. +, L.T.—; 2 battery tags, 1 Wanderfuse, 1 twin socket strip (" *Belling Lee* ").

Batteries.—1 No. 1060 Drydex Special Q.P.P. (" *Exide* "); 1 No. 1002 G.B. 16½-volt Drydex (" *Exide* "); 1 2-volt accumulator, No. HZ4 (" *Exide* ").

Ebonite.—1 strip 6½ by 2 by 3/16 inches (" *Becol* ").

Wiring.—1 coil " Glazite " (" *Lewcos* ").

TEST RESULTS

The addition of this amplifier to a normal 2-valve battery set resulted in a power output of about 1·7 watts, using a " Rola " speaker. The volume of sound is far more than is needed for domestic use under ordinary conditions. Purity and brilliance of reproduction are much improved.

Note that if a Celestion special Q.P.P. speaker is used the output transformer will not be needed.

LAYOUT OF BASEBOARD

The components are grouped in an orderly manner—the whole can be housed in a neat case, or, if space allows, within the receiver cabinet.

SHORT WAVE AUTODYNE FOUR

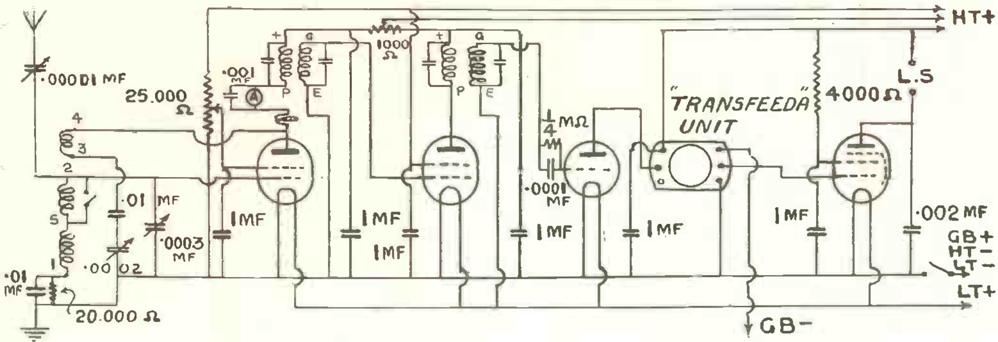


Fig. 9.—Circuit for Short Wave Autodyne Four.

SPECIAL FEATURES

A dual range receiver covering the useful wave band of 18 to 64 metres. An autodyne type of superheterodyne receiver, has an excellent range when properly handled.

A milliammeter is included in the circuit to provide a visual indication that the first valve is on the oscillation point. The first valve acts as an anode bend first detector and oscillator, the second valve is the I.F. oscillator, then follows a detector, transformer coupled to a pentode output valve.

Potentiometer control of screen potential is provided to enable the critical control that is essential to success in reception.

The I.F. transformers have built-in trimming condensers; they must be adjusted accurately in the set.

COMPONENTS REQUIRED

Coil.—1 K.S.W. with switch ("*Colvern*").

I.F. Transformers.—2 Colverdynes type 150 ("*Colvern*").

Tuning Condenser.—1 ·0003 S.L.F., S.W. with S.M. drive ("*Jackson Bros.*").

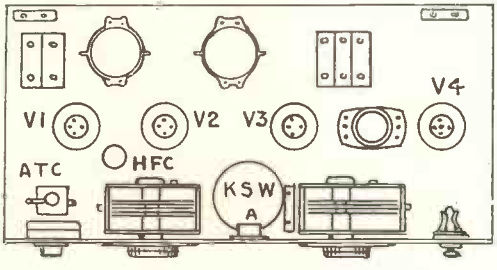


Fig. 9a.—Layout of Components.

Reaction Condenser.—1 ·00025 S.L.F., S.W. with S.M. drive ("*Jackson Bros.*").

Aerial Condenser.—1 "Neutralising" ("*Jackson Bros.*").

Fixed Condensers.—1 Flat M. Type, ·0001 ("*T.C.C.*"); 6 1 mfd.; 1 ·002 mfd.; 2 ·01 mfd.; 1 ·001 mfd. ("*T.C.C.*").

Resistances.—1 4,000 ohms, 1 20,000 ohms Spaghetti ("*Lewcos*").

Grid Leak.—250,000 ohms, 2 10,000 ohms "metallised" ("*Dubilier*").

H.F. Choke. — 1 S.W. Type HF, SW. ("*Igranic*").

Potentiometer. — 1 25,000 ohm ("*Lewcos*").

Valve Holders.—3 4-pin, 1 5-pin ("*Wearite*").

Ammeter.—0–10 ma. Flush panel type ("*Bulgin*").

Terminals.—6 Wanderplugs, 1 Wanderfuse, 2 battery tags, 2 twin socket strips ("*Belling Lee*").

L.F. Transformer.—1 "Transfeeda" unit ("*Benjamin*").

Loud Speaker.—1 F6 P.M. ("*Rola*").

Valves.—2 SG215, 1 L2, 1 Pen. 220 ("*Mazda*").

Batteries.—1 No. H1012 "Drydex"; 1 No. 1002 "Drydex" ("*Exide*"); 1 Gel-Cel JWF7 ("*Exide*").

Baseboard.—20 by 10 by ⅜ inches covered "Konductite" ("*C. A. C. Cabinets Ltd.*").

TEST DIAL SETTINGS

Dial settings are not given for this set, in common with others of a similar type, the same station can be received at two different settings.

A.C. THREE-VALVE RECEIVER

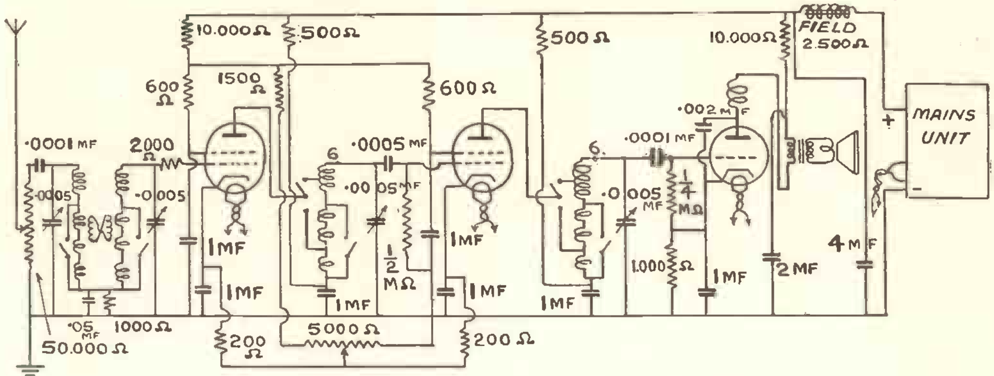


Fig. 10.—Circuit for A.C. Three-Valve Receiver.

SPECIAL FEATURES

Great range and selectivity are the outstanding features of this set; it is not recommended for local reception. Two S.G. H.F. stages are followed by a detector; band-bass tuning with ganged tuning condensers and ganged wave-change switch.

COMPONENTS REQUIRED

Coils.—2 K.B.L.C., 2 K.G.O. ganged on chassis (" *Colvern* ").

Tuning Condenser.—4 gang ·0005 " Nugang " with slow motion drive (" *Jackson Bros.*").

Fixed Condensers.—1 ·05 mfd.; 7 1 mfd.; 1 2 mfd.; 1 4 mfd.; all 400 V.D.C. working (" *T.C.C.*"); 2 ·0001 mfd.; 1 ·002 mfd.; 1 ·0005 mfd. (" *T.C.C.*").

Resistances.—Strip type, 2 10,000 ohms; 1 1,500 ohms, 2 600 ohms (" *Igranic* "); 1 2,000 ohms, 1 ½ megohm; 1 ¼ megohm; 2 1,000 ohms metallised (" *Dubilier* ").

Resistances. — Super-Biassing Spaghetti, 2, 200 ohms (" *Bulgin* ").

Potentiometers.—1 50,000 ohms; 1 5,000 ohms (" *Lewcos* ").

Valve Holders.—3 4-pin (" *Wearite* ").

Valves.—2 AC/SG.; 1 AC/HL (" *Mazda* ").

Mains Unit.—" Popular Power Pack " (" *Heayberd* ").

Loud Speaker.—Type F.6 Field Excited Moving Coil (" *Rola* ").

Baseboard.—13 by 13 by ⅜ inches thick covered with " Konductite " metallic paper (" *C. A. C. Cabinets Ltd.*").

TEST DIAL SETTINGS

This set brings in over 100 European and American M.W. stations; the following are specimens :—

Fecamp	16½	Belgrade	127
Nurnberg	19	Brussels No. 1	164
Horby	23	Eiffel Tower	90
Scottish National	51	Lahti	150
Huizen	53	Pittsburgh U.S.A.	51
Goteborg	58	Atlantic City, U.S.A.	33
Barcelona	62		
London Regional	67		
Algiers	69½		

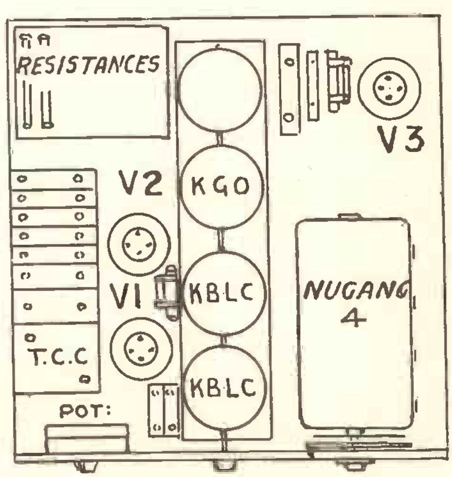


Fig. 10A.—Layout of Components.

A.C. MAINS RADIOGRAMOPHONE

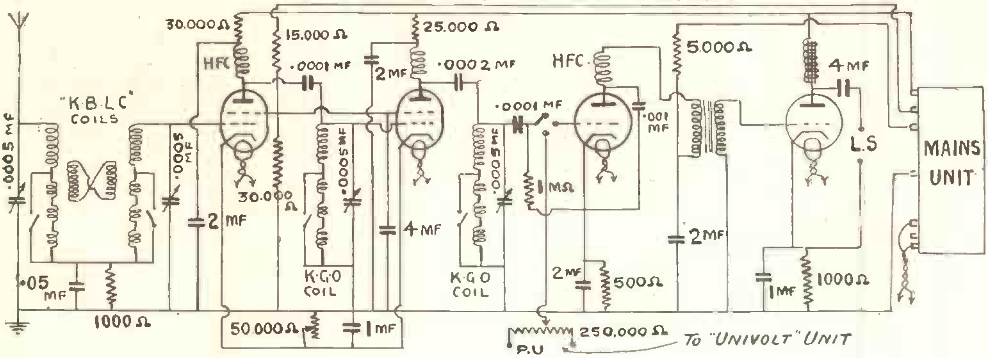


Fig. 11.—Circuit for A.C. Mains Radiogramophone.

SPECIAL FEATURES

A powerful radio receiver that will bring in dozens of stations at good strength, combined with a very powerful electric gramophone player.

COMPONENTS REQUIRED

Coils.—2 K.B.L.C. ; 2 K.G.O. ("*Colvern*").

Tuning Condenser.—4 gang "Nugang" ·0005 mfd. with slow-motion dial ("*Jackson Bros.*").

H.F. Chokes.—2 HFPA., 1 HFP ("*Wearite*").

Fixed Condensers.—5 2 mfd. ; 3 1 mfd. 500 V.D.C. ; 1 ·05 mfd. non-inductive ; 1 each ·001 mfd., ·0003 mfd., ·0002 mfd., ·0001 mfd., ·00005 mfd. ("*T.C.C.*").

Valve Holders.—4 5-pin ("*Wearite*").

Fixed Resistances.—1 each 500 ohms, 1,000 ohms, 10,000 ohms, 30,000 ohms, 40,000 ohms, 50,000 ohms ; 2, 20,000 ohms ("*Dubilier*").

Grid Leak.—1 megohm ("*Dubilier*").

Variable Resistances.—1 50,000 ohms ; 1 250,000 ohms and change-over switch combined ("*Wearite*").

Switch.—1 Mains Type S86 ("*Bulgin*").

L.F. Transformer. — AF7 ("*Ferranti*").

L.F. Choke.—No. LF21 ("*Bulgin*").

Loud Speaker.—"Reetone" matched pair S.29 ("*Celestion*").

Mains Unit.—G200 ("*Heayberd*").

Valves.—2 AC/SG, 1 AC/HL, 1 AC/P "*Magda*").

Electric Gramophone.—1 complete "Univolt" unit, combining base, turntable, pick-up and control complete ("*Univolt Electric Ltd*").

TEST DIAL SETTINGS

A few only for calibration purposes :—

Fecamp	10	Beromunster	75
London National	18	Vienna	94
Genoa	34	Radio Paris	57
London Regional	49	Daventry	49
Athlone	61	Eiffel Tower	31

BASEBOARD LAYOUT

The arrangement shown is suitable for a console type of cabinet, the Univolt being placed on the right of the receiver.

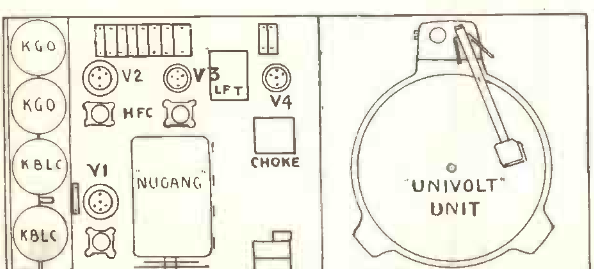


Fig. 11a.—Layout of Components.

D.C. MAINS THREE-VALVE RECEIVER

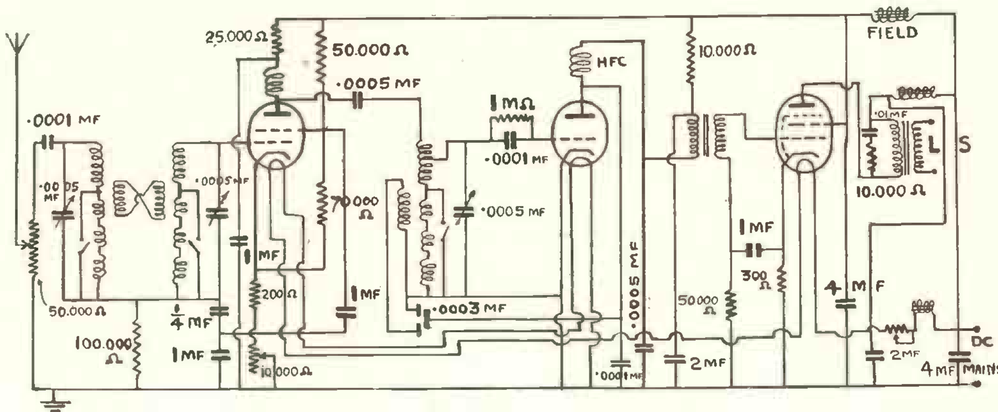


Fig. 12.—Circuit for D.C. Mains Three-Valve Receiver.

SPECIAL FEATURES

The usual precautions when operating a receiver from D.C. mains, including fuses, switches and insulation, must be taken.

COMPONENTS REQUIRED

Coils.—2 K.B.L.C., 1 K.G.R., ganged on chassis ("*Colvern*").

Tuning Condensers.—Triple ganged ·0005 mfd. "Nugang" with slow motion drive ("*Jackson Bros.*").

Reaction Condenser. — ·0003 mfd. differential. Complete with knob and dial ("*Jackson Bros.*").

Transformers. — 1 Type L.F. T6 ("*Lewcos*"); 1 Type O.P.M. ("*Ferranti*").

Valve Holders.—3 5-pin ("*Wearite*").

Fixed Resistances.—2 100,000 ohms; 1 300 ohms; 2 10,000 ohms; 1 200 ohms; 1 50,000 ohms; 1 70,000 ohms; 1 25,000 ohms; ("*Dubilier*").

Grid Leak.—1 megohm metallised; ("*Dubilier*").

Fixed Condensers.—2 ·0001 mfd.; 4 ·0005 mfd.; 1 $\frac{1}{4}$ mfd. non-inductive; 2 4 mfd. 500 V.D.C.; 2 1 mfd. non-inductive 500 V.D.C.; 2 2 mfd. V.D.C.; 1 ·0003 mfd. ("*T.C.C.*").

L.F. Chokes.—1 L.F. 200 ohms 10 henrys to carry 1 amp. ("*Heayberd*"); 1 L.F. 500 ohms 20 henrys ("*Heayberd*").

H. F. Chokes.—1 Type HFC, 1 Type M.C. ("*Lewcos*").

Voltage Regulating Resistance.—Resistance value to suit mains, to pass 25 volt 1 amp. for filament heater circuit ("*Heayberd*").

Valves.—1 DC2SG; 1 DC3HL; 1 DC2 Pen ("*Mazda*").

Potentiometers. — 2 50,000 ohms ganged type Q.V.C. ("*Wearite*").

Baseboard.—18 by 12 by $\frac{1}{2}$ inches plywood faced with "Konductite" ("*C. A. C. Cabinets Ltd.*").

Loud Speaker.—Type F7 2,500 ohms, field excited, for D.C. mains ("*Rola*").

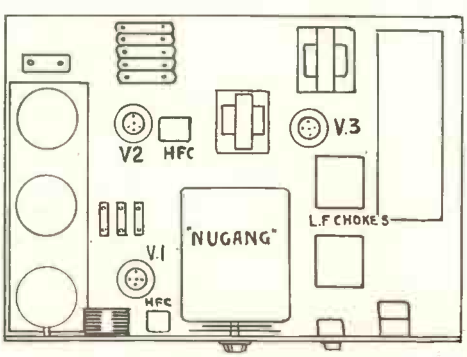


Fig. 12a.—Layout of Components.

TEST DIAL SETTINGS

Trieste	23	Midland	
London National	28	Regional	109
Hilversum	52	Sottens	114
Poste Parisien	70	Radio Paris	148
London Regional	84	Daventry	122

THE QUIESCENT FOUR

By EDWARD W. HOBBS, A.I.N.A.

THE outstanding feature of this set is a loud speaker output of approximately $1\frac{1}{2}$ watts A.C. with a H.T. battery consumption of rather under 8 milliamperes at full load and about $5\frac{1}{2}$ milliamperes at normal load. The volume of undistorted sound is comparable to that from a mains set, the tone and quality are good, while the set itself (Fig. 1) with built-in speaker and batteries, is neat and compact. The cost is quite modest considering the results.

Principles of Quiescent Push-Pull

The principles of Q.P.P. are fully dealt with elsewhere in COMPLETE WIRELESS. Suffice it to mention that these remarkable results are due to the use of special components, the method of adjusting the grid bias and balancing the output valves. There are, however, a number of practical points that call for consideration when constructing a Q.P.P. receiver to which attention is here chiefly directed.

Where Q.P.P. Excels

For local station reception at large volume the Q.P.P. scheme is unrivalled at the present time. It yields all the volume that is needed for domestic purposes, but can be reduced to a whisper by adjusting the volume control potentiometer which regulates the S.G. valve screen voltage. The set described herein is too powerful for average-size living-rooms, but on the other hand, reception of distant stations is not proportionately so good as that obtainable with an orthodox straight four-valve circuit. This set will, however, give a good selection of really worth-while stations—a practical choice of about twenty stations. To obtain the full advantage of Q.P.P. the last valves must be fully loaded.

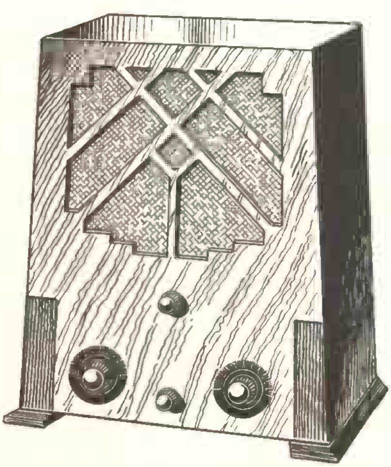


Fig. 1.—THE COMPLETED RECEIVER.

Gramophone Reproduction

One other advantage of Q.P.P. reception must be mentioned, and that is the remarkable results obtainable from gramophone reproduction.

The average battery set does not yield an acoustic output much in excess of the unaided gramophone, but with this Q.P.P. set—which is provided with pick-up sockets—the volume of sound obtainable from gramophone records is amazing; the tone and quality are exceptionally good.

This set gives splendid results when a B.T.H. Senior de Luxe pick-up with combined volume control is employed.

Components Required

The following comprises a list of components needed for this set. It should be pointed out that the use of the specified transformer, loud speaker, batteries and coils are essential, and readers are recommended to adhere to the specification in detail.

COILS.—1 RM1S; 1 RM3S ("*Colvern*").

TUNING CONDENSER.—1 "Nugang" twin ·0005 mf. ("*Jackson Bros.*").

REACTION CONDENSER. — 1 "Tiny" ·0003 mf. with slow motion drive ("*Jackson Bros.*").

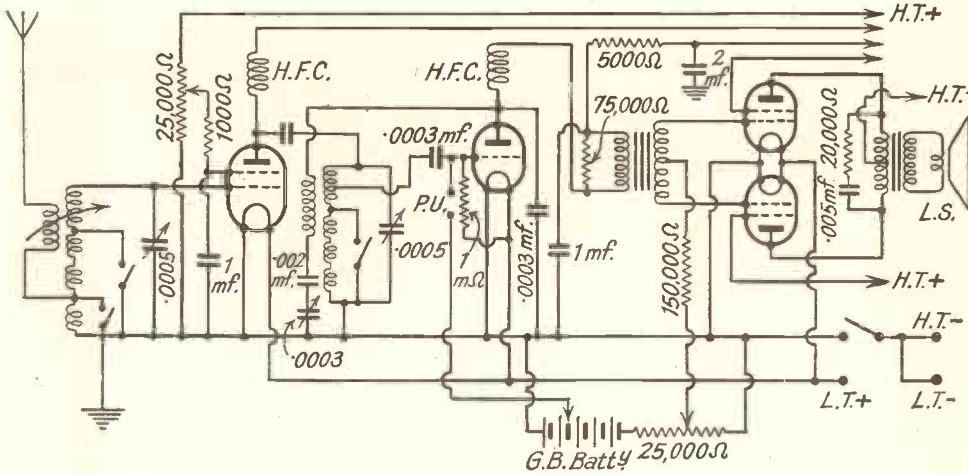


Fig. 2.—Circuit of the "Quiescent Four."

A S.G valve, followed by a detector with two pentodes in Q.P.P. Variable aerial coupling ensures adequate selectivity.

Screening Cans.—2 cans and bases to suit coils (type CCS) ("*Colvern*").

H.F. Chokes. — 1 Type HFPA ("*Wearite*"); 1 Midget ("*Lissen*").

Intervalve L.F. Transformer.—1 AF12C — Q.P.P. Audio transformer ("*Ferranti*").

Fixed Condensers.—2 flat M type

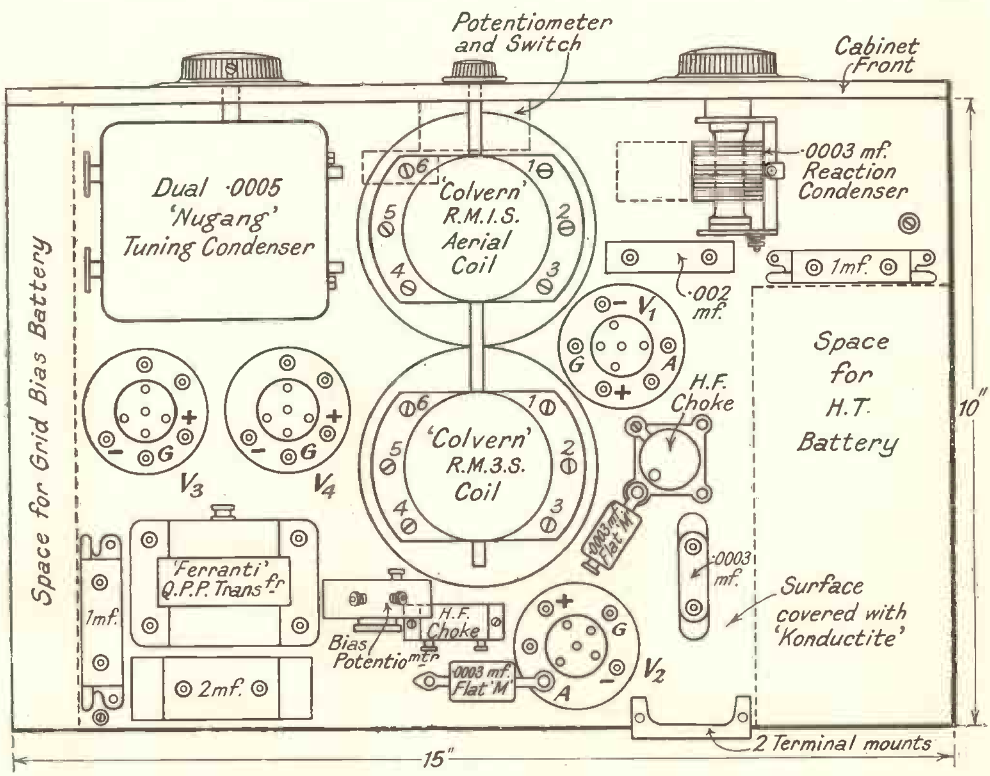


Fig. 3.—The Layout of the Components on the Baseboard.

·0003 mf. ("*T.C.C.*"); 2 1 mf.; 1 2 mf. 400 V.D.C. ("*T.C.C.*"); 1 ·0003 mf. type 40; 1 ·005 mf. ("*T.C.C.*"); 1 ·002 mf. ("*T.C.C.*").

POTENTIOMETERS.—1 25,000 ohm wire wound ("*Lewcos*"); 1 Q.V.C. 25,000 ohm ganged with Q.M.B. on-off switch ("*Wearite*").

RESISTANCES.—1 5,000 ohms; 1 75,000 ohms; 1 150,000 ohms metallised ("*Dubilier*"); 1 20,000 ohms; 1 1,000 ohms spaghettis ("*Lewcos*"); 1 1-megohm grid leak ("*Dubilier*").

VALVE HOLDERS.—4 5-pin ("*Godwinex*").

LOUD SPEAKER.—1 Model M.C. 22 Q.P.P. for 18,000 ohms load ("*Amplion*").

CABINET.—1 Model 60 in walnut with baseboard covered "Konductite" ("*C.A.C. Cabinets Ltd.*," 7, Angel Court, London, W.C.2).

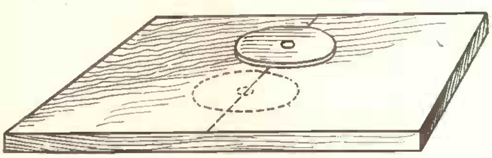


Fig. 4.—LOCATING SCREENING CAN BASES.

These are located by a centre hole placed over a centre line on the baseboard.

TERMINALS.—2 terminal mounts, 4 R type terminals marked A.E. P.U. P.U., 7 wander plugs, 1 wanderfuse, 2 battery tags ("*Belling-Lee*").

VALVES.—1 PM 12A metallised ("*Mullard*"); 1 HL2 metallised ("*Mazda*"); 2 Pen. 220A ("*Mazda*").

BATTERIES.—1 special Q.P.P.; 130-v. Drydex No. 1060 ("*Exide*"); 1 $16\frac{1}{2}$ V.G.B. No. H1002 ("*Exide*"); 1 2-volt Gel-Cel No. J.W.F7 ("*Exide*").

SUNDRIES.—1 sheet "Konductite" metallised paper ("*City Accumulator Company*").

WIRING.—1 coil red, 1 coil black, 1 coil yellow ("*Glazite*"); 4 yards red "Lewcoflex" ("*Lewcos*").

Having obtained and checked over all the parts proceed to assemble them in the order now to be described.

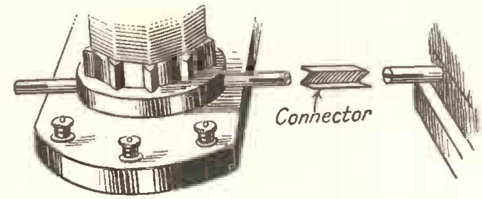


Fig. 5.—GANGING THE WAVE-CHANGE SWITCHES.

Align the two coils as described in text, then connect the switch spindles with the Z-sectioned connectors.

What to do First

Remove the baseboard from the set—it measures 15 inches long, 10 inches wide and is $\frac{3}{8}$ inch thick—ready covered with "Konductite" metallised paper, to which earth connections can be made in the same way as to ordinary foil.

Draw a pencil line across the centre of the baseboard, then locate the two Colvern coil screen bases on this centre line, as shown in Fig. 4, and fasten them down by small screws through the centre holes. Next, adjust the bases by turning them until the coil fastening screw holes come in the proper places so that the coils can be screwed down and will then come in line with terminals Nos. 1-2-3 on the left—as shown in the baseboard lay-out (Fig. 3).

Ganging the Wave-change Switch

The wave-change switches are built into the coil bases and have to be connected together by means of the Z-shaped sectioned rods supplied with the coils. Cut a piece to length and slip it into the slot in the end of the switch spindle as shown in Fig. 5, then slide the whole into the slit in the end of the second coil spindle. Take care that the two switches are in the same relative position when connecting them.

Fixing the Condensers

Next fix the ganged "Nugang" condenser to the baseboard, securing it as shown in Fig. 6, the screws being let into recesses or

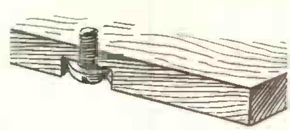


Fig. 6.—COUNTER-BORED HOLES.

Drill the underside of baseboard to enable screw heads to sink in flush.

" counterbores " on the underside of the base—so that the heads are beneath the surface.

The reaction condenser can be secured to the baseboard with two small plates—as shown in Fig. 7—one is bent to a right angle, the other is cranked; both are bent to shape with pliers, the metal used being the clips supplied with the grid condenser and not required for the leak on this set.

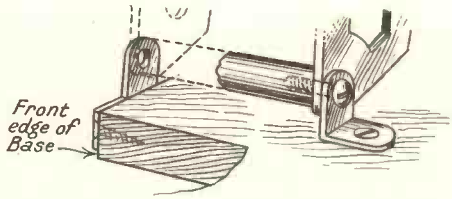


Fig. 7.—Fixing Reaction Condenser.

Two metal plates shaped as here shown are needed to hold the reaction condenser in place.

Screw one clip to the top of the baseboard and the other to the front edge; adjust the spindle position so that it is 4 inches from the centre line of base and is at the same height as the tuning condenser spindle. Note that the condenser frame and moving plates are earthed to the metallised base.

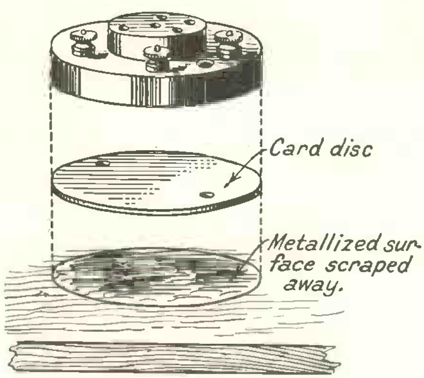


Fig. 8.—Safeguarding the Valves.

Clear away the metallised surface beneath the valve holders and place a disc of card under each before screwing to baseboard.

The Valve Holders

The next step is to fix the valve holders—but take care to remove the metallised paper from the base, also place a disc of stout card under each valve holder—as in Fig. 8—otherwise the valve pins would short-circuit. Then fix the other components into place, taking care to leave spaces at each side of the base for the G.B. and H.T. batteries, as indicated in Fig. 3.

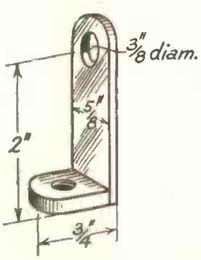


Fig. 9.—Bracket for Bias Potentiometer.

A thin wooden or ebonite bracket as here shown is required for the bias potentiometer.

The bias potentiometer has to be fixed to a neat wooden bracket as shown in Fig. 9, and care taken that it is, and will remain, insulated from the base.

Terminal Mount

Two B-L terminal mounts are used for the A. and E. terminals and for the pick-up terminals respectively.

These must be mounted carefully or a short-circuit will be possible *viâ* the metallised base. The best arrangement is sketched in Fig. 10. Note that the metallisation is cleared away beneath the ebonite mount; this is essential as the fixing screws would otherwise short-circuit through the foil should a strand of wire come into contact with either of them.

Beginning the Wiring

Fix the various resistances in place, also the two flat M-type condensers, one between anode of detector and base, the other to the H.F. choke. The surplus metal around the tags should be clipped off as required.

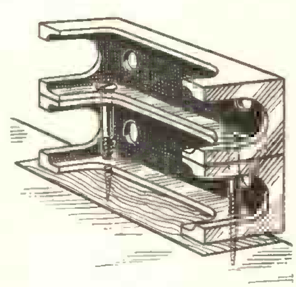


Fig. 10.—Fitting the Terminal Mounts.

Two Belling-Lee terminal mounts are placed one above the other and screwed to the baseboard. Aerial and earth terminals are fitted to the upper mount, pick-up terminals to the lower mount.

Next run all the various earth wires in black glazite, and make sundry connections direct to the metallised base—as shown in Fig. 11 (note that the L.T. negative wires are here treated as " earth " wires). It is imperative that the valve

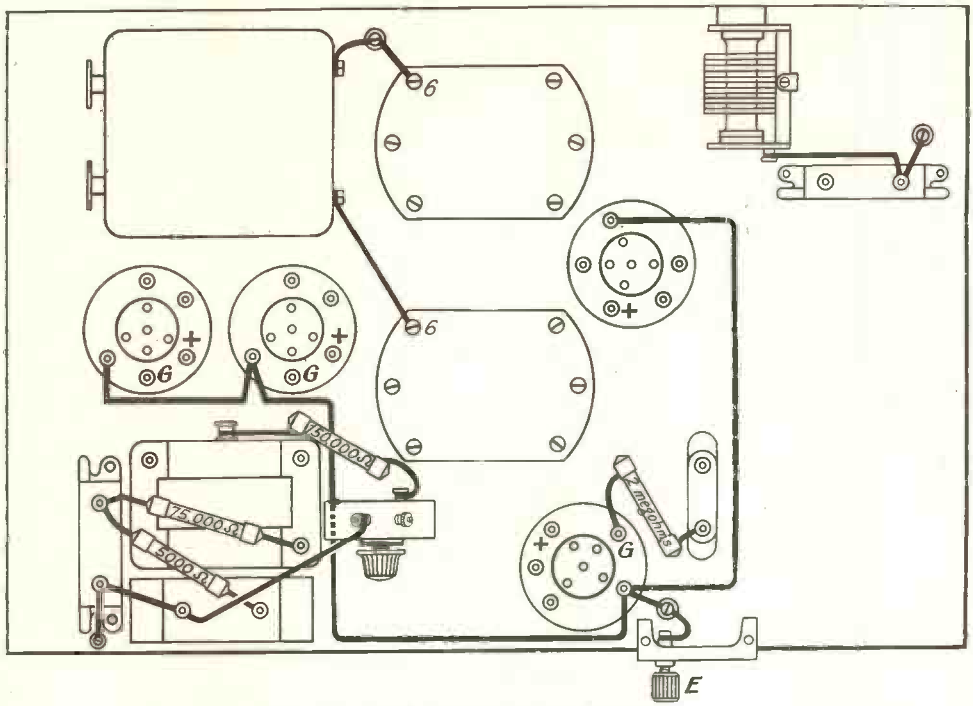


Fig. 11.—First Stage of the Wiring.
Run all earth wires and the L.T. – wires in black glazite. Then fix the various resistances.

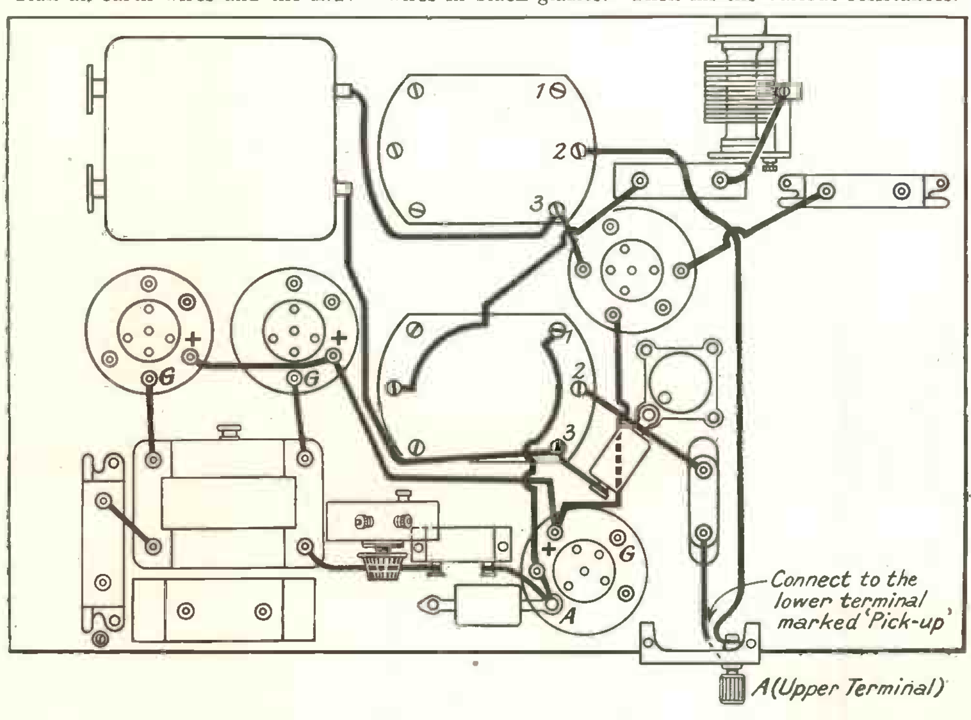


Fig. 12.—Second Stage of the Wiring.
Wires already fixed are **not** shown, but only those next to be fitted in red and yellow glazite are shown.

filaments be at correct polarity—as shown in Fig. 11—the L.T.—must be connected to valve pin No. 3 in every case.

The Main Wiring

Run the L.T. + leads in red glazite and the H.T. + leads in yellow glazite, arranging them as shown in Fig. 12, then run the numerous "flex" leads—as shown in Fig. 13—taking care to make neatly soldered eyes or tags on the ends of all of them, otherwise there may be trouble with straggling ends of flexible wire.

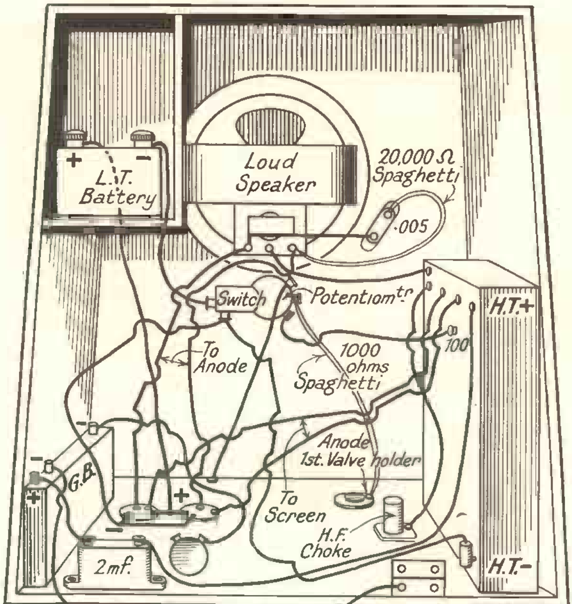


Fig. 13.—COMPLETION OF WIRING.

The paths of the various flexible leads in the cabinet are here shown—the components being omitted for clarity.

Take care that the loud speaker is connected properly; the centre (green) terminal goes direct to 130½ volts H.T. + on the battery—the "common" terminal is to be connected to the anode of one output valve, and the "red" terminal to the anode on the second output valve.

When handling the loud speaker take care to keep it free from dust, particularly that no grit or dust gets into the "pot" gap—or rattle will be caused thereby. At the same time fix the ·005 mf. condenser beside the speaker on the baffle-board and connect one end of the 20,000 ohms spaghetti resistance to one terminal on the condenser. Connect the other condenser terminal to "common" terminal; connect free end of resistance to "red" terminal on the loud speaker.

Preliminary Adjustments

The first adjustments should be made with the baseboard out of the case—for which purpose long temporary leads should be connected to the screen potentiometer and speaker.

Connect the set to aerial and earth, switch "off"—place the first valve, the detector valve and one pentode valve in their sockets. Connect all leads to batteries except the screen lead from the empty valve holder. Note that if five-pin pentode valves are used these leads go to the "centre" terminal, but if four-pin pentodes are used the connections go to the side terminals. Note that no adjustments that necessitate removing a wander plug or otherwise breaking either the H.T. + or the bias circuits must be made until the L.T. filament circuit has been opened—that is the filament circuit must always be "off"—otherwise voltage surges will probably damage the valves.

Fig. 14.—MILLIAMMETER CONNECTIONS.

To adjust the Q.P.P. valves properly insert a milliammeter in the main H.T.+ lead, and follow the directions in text.

Setting the Bias Current

With the valves and circuit arranged as described, insert a low-reading milliammeter in the H.T. + lead to the speaker, as shown in Fig. 14, then turn the bias potentiometer to the left, as seen from the back, so that the whole $16\frac{1}{2}$ volts can pass; then turn it back a trifle.

Switch on; the milliammeter should then read about 2 to 3 milliamperes; if not, adjust the screen voltage and the potentiometer until a value of 2 milliamperes is obtained.

Switch off, remove the first pentode and place the second pentode into its proper holder. Connect the next nearest tapping on H.T. battery, then switch on. If the reading is close to 2 milliamperes all is well; if not, adjust the H.T. + screen voltage until a reading of 2 milli. amperes is obtained without altering the potentiometer setting.

Replace the first pentode, connect up, switch on, and tune in a station. The volume will be astonishing, but there are still a few adjustments to make.

Aerial Coupling

Selectivity is controlled by the rotor in the first coil. When it is vertical reception is almost impossible; when the rotor is horizontal, selectivity is at a minimum and volume at the maximum. Adjust the coil to give the best average results.

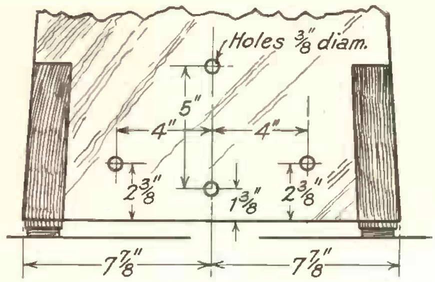


Fig. 15.—ARRANGEMENT OF CONTROLS ON CABINET FRONT.

Holes ⅜ inch diameter are drilled through the cabinet as here shown. The volume control and combined on-off switch is fixed to the cabinet, all others are fixed to baseboard.

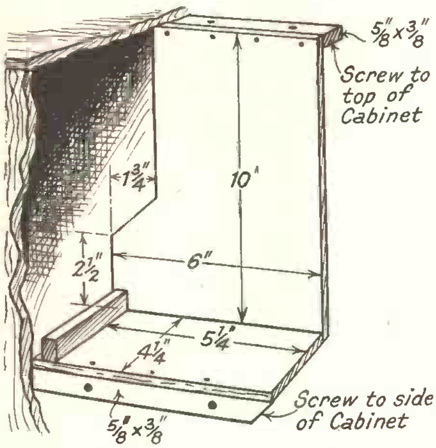


Fig. 16.—SUPPORTING BRACKET.

Built of pine ¼ inch thick, this support is screwed to the inside of the cabinet and forms the shelf for the L.T. battery.

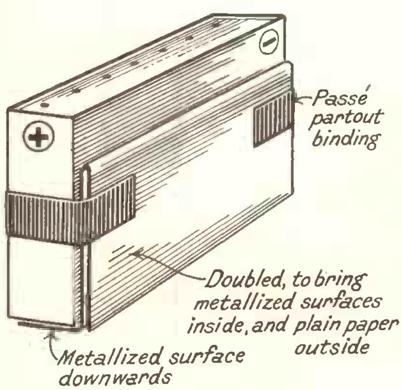


Fig. 17.—COVERING THE G.B. BATTERY WITH "KONDUCTITE."

Ganging the Tuning Condensers

Place both coil screens in position before ganging; unscrew both star wheels, tune in a station near one end of the dial—keep the volume low—adjust the trimmers for maximum signal strength; repeat the operation at the opposite end of the dial.

A very slight movement of the trimmer will make a great difference. Place the base into the cabinet after drilling the four control spindle holes as shown in Fig. 15. Put the L.T. accumulator on a special shelf as shown in Fig. 16; cover the shelf and batteries with "Konductite" as shown in Figs. 16 and 17, to form earthed shields.

Cut a small opening through the back board to provide access to the terminals.

The Circuit

The circuit is given in Fig. 2, but it is possible to use most types of existing moving-coil speakers on the Q.P.P. system by using a special "Ferranti" Type OPM 12 C output transformer.

A circuit showing this, and one for a Q.P.P. amplifier to follow any set are given in the article on "Sixteen Tested Circuits" elsewhere in COMPLETE WIRELESS.

SERVICING THE PHILCO TRANSITONE

A SPECIALISED RECEIVER FOR USE IN MOTOR CARS

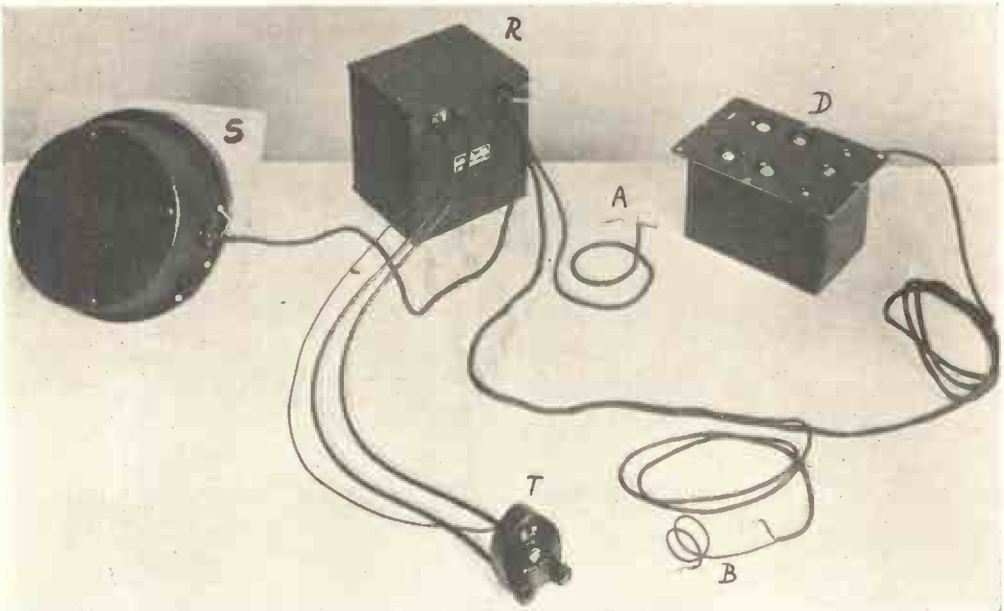


Fig. 1.—THE PHILCO TRANSITONE, MODELS 9 AND 12, WIRED FOR OPERATION.

The Models 9 and 12 are identical in every respect except that they are intended for fitting to cars having a 6-volt and a 12-volt starter battery respectively. R is the receiver unit which is tuned by the tuning unit T. The leads, B, connect to the car starter battery, which supplies power for the set, the moving coil speaker, S, and the dynamotor, D. The aerial connects to the shielded lead, A. This set gives an undistorted output of 5·5 watts.

THE following is a description of the latest Philco "Transitone" Automobile Radio Receivers, and gives a detailed description of all the various factors peculiar to mobile radio and the influence they have had in the evolution of the present sets.

Small Dimensions

Particular interest attaches to the surprisingly small physical dimensions of these receivers, which have a sensitivity outclassing almost any domestic receiver on the market and yet whose performance is unaffected by the strong electrical fields due to the ignition and generator systems of the car. A big reserve of undistorted volume from the speaker obtained by the use of a "Class B" output stage is made available, and the automatic volume control is fully effective on all signals. The Class B output circuit is, as yet, practically unknown in this country, but should soon become popular owing to the great advantages conferred over the more conventional "Class A" systems used up to now, providing the transformer manufacturer and the valve manufacturer work in absolute collaboration.

What is the "Transitone?"

Figs. 1 and 2 are illustrations of a complete Model 9 receiver and a complete Model 6 receiver connected up ready for operation.

These, it is seen, consist of four essential units, the moving coil speaker on the left, the receiver unit in the centre, the dynamotor unit on the right, and finally the smallest, the tuning unit in the foreground.

The Tuning Unit

After installation in the car, the tuning unit is the only visible portion of the complete set, and is mounted in any position convenient to the hand of the operator, usually on the steering column as in Fig. 9. The dial is kilocycle-calibrated, and is illuminated from the rear, having green figures on a black ground. The illumination is sufficient for easy reading but not so bright as to cause the driver any inconvenience when driving at night-time. The left-hand knob is the manual volume control and on-off switch, and the other is the tuning control. The tuning unit has been designed to permit effortless one-handed tuning whilst driving, and is a great improvement over other methods which have been tried, and allows the actual receiver to be tucked away completely out of sight.

The Control Shafts

Manual operation of tuning and volume is thus obtained conveniently to the hand of the operator, but the volume control and the tuning condenser are actually located within the receiver unit itself, these being linked up to the tuning unit knobs by means of two flexible control shafts. Various lengths of control shafts are available, from 18 inches long up to 120 inches long in order to facilitate installation in any type of car. Thus the receiver unit may be placed anywhere in the car up to 10 feet away from the tuning unit, and the physical relationship between the two units is of no moment. This makes unusual installations no more difficult than a standard installation. For example, the only convenient place for the receiver unit to meet certain demands of the owner may be beneath the floorboards in the rear of the car, but the tuning unit may still be fitted on the steering column, or perhaps

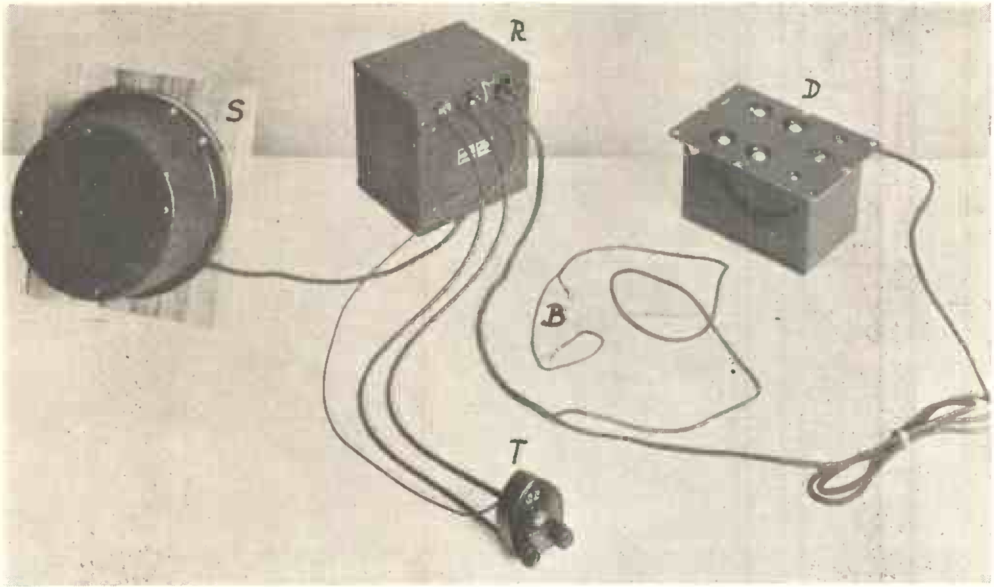


Fig. 2.—THE PHILCO TRANSITONE, MODEL 6.

The reference letters are the same as for Models 9 and 12 in Fig. 1. The output of this set is 1·6 watts—ample for all normal requirements. Note the independent speaker cable; two connecting plugs are used on a different wiring harness, otherwise all sets are physically identical.

The aerial connects to an independent shielded lead which is brought out at the back of the set. This installation is for 6-volt operation only.

the receiver may be put in its normal position under the car instrument panel, and yet the tuning unit made accessible to the rear-seat passengers if required.

The Dynamotor

In the course of six years' experience in the design and servicing of Transitone receivers it has been more and more evident that the human element must be cut out of automobile radio if the complete satisfaction of the user is always to be assured, and this has led to the elimination of all replaceable batteries and their substitution by a dynamotor unit which will deliver unvarying power at all times and never require even periodic attention. This has at once made it possible to use valves capable of giving a much superior performance, together with a very necessary large reserve of volume from the speaker to meet the needs of unusual conditions often encountered whilst travelling.

Fig. 3.—FRONT ELEVATION WITH FRONT COVER REMOVED. ALL MODELS.

Four valves are visible, the RF input valve RF, the modulator oscillator O, the IF. amplifier inside its padded screen IF, and the Duo-Diode-Triode-detector and AVC valve D. Note the clip PL, which takes the tuning dial pilot lamp lead, and the holes V and T, which are the points of entry for the volume control (and switch), and tuning cables respectively.

CS is the cable socket into which the plug on the wiring harness fits and effects all external connections.

Note also the worm drive for the tuning condenser which prevents alteration of tuning due to vibration.

The degree of interference (due to electrical parts of the car) which has to be suppressed is already high, and therefore in the past it has been generally thought that the substitution of batteries by a motor-generator would add unduly to this already sufficiently difficult problem. Due to great advances in small motor and generator design, and to the result of the efforts of the Transitone Research Laboratories, Philco have produced the small combined unit illustrated in Fig. 7.

High Voltage D.C. Output

Electrically, this is a high-efficiency combined instrument giving an output of 220 volts at 40 milliamperes for an input current of 3 amperes in the case of the 6-volt unit. This high voltage D.C. output is already reasonably ripple-free at the brushes, and after it has passed through the integral smoothing unit and R.F. choke, which may be seen in the illustration, it is delivered as battery-smooth power for the receiver at the output terminals.

Silent Running

Mechanically, much thought has been given to the design. Complete silence is obtained while running by the fact that the four feet of the rotary unit are mounted on thick resilient rubber pads, thus preventing transmission of armature vibration to the housing box with consequent complete silence.

Position of the Dynamotor Unit

The dynamotor unit is intended to be sunk in the floorboards of the car, and may be permanently covered up, as no attention will at any time be required, even for oiling, the armature bearings being so designed that no oil is required, *and oil must never be applied*, otherwise trouble will occur !

The Receiver Unit

As already mentioned, the receiver unit is built to the smallest possible dimensions, and a choice of two mountings is available, back mounting or side mounting according to the dimensions of the location where it is to be fitted within the car.

The case is black crackle-finished pressed steel, and is completely sealed, thus making it absolutely watertight. Heat dissipation from the valves is more than adequate by conduction through the metal case.

In the Model 6 there are two plug sockets on the front of the case for coupling up to all external connections, the aerial alone being brought through the case for external connection *viâ* a length of shielded cable. In the Models 9 and 12, only one 6-pin socket carries *all* external connections including the aerial.

As may be seen from Figs. 1 and 2, plugs carried on a ready-made-up completely shielded wiring harness fit these sockets, and the various leads from the harness are then led and connected to their respective units, surplus wire being cut off as may be required.

The tuning unit on the steering column is coupled to the combined volume control and on-off switch, and to the tuning condensers, through flexible couplings, as already described.

Examination of Figs. 3 and 4 will demonstrate that no space has been wasted inside the case; in Fig. 3 the volume control can be seen inside the top left of the casing. On the back of the volume control is a double pole on-off switch which completes the dynamotor motor circuit and the valve filament circuit; this, of course, is operated from one of the remote tuning unit knobs.

Fig. 4.—The Underside of the Model 9.

Note the essentially short wiring employed. All resistors and small fixed condensers are firmly anchored and cannot shift.

The picture shows the oscillator low-frequency trimmer being adjusted with a fibre wrench for maximum signal. The other three trimming condensers are all intermediate-frequency (260 Kc.) padders.

The Local-Distance switch on the side of the case can be clearly seen.

Performance — The result of Sturdy Construction

To the right of this control can be seen the worm and quadrant gear drive of the die-cast hardened aluminium tuning condenser. This gear is machined to extremely fine limits, thus the setting of the vanes cannot alter under the most extreme vibration of the car, so that the necessity for constant retuning whilst on the move is eliminated. This at the same time permits the accurate calibration of the distant tuning dial since there is complete absence of "backlash" throughout the drive.

How it works

Coming in over the aerial, the energy is fed to the type 36 R.F. amplifying valve which is the valve on the extreme right in Fig. 3. The energy reaches this valve through the aerial transformer, the primary winding of which is shunted by a resistor in order that aerials of varied dimensions may be used without affecting the selectivity or performance of the receiver. It is important that this resistor be of correct value, otherwise a decided

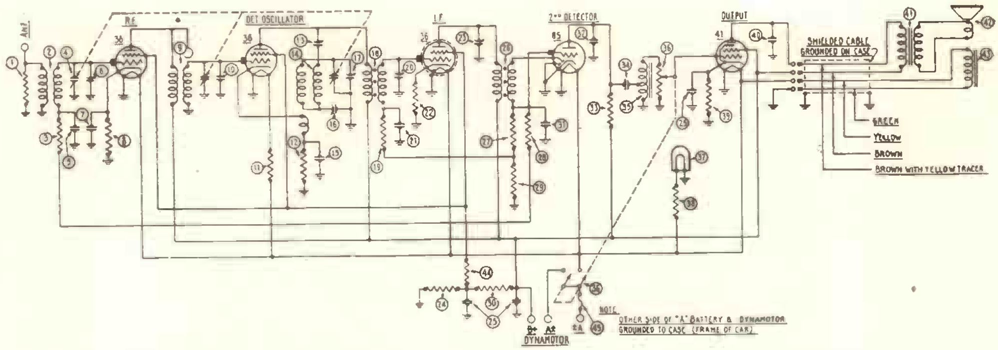


Fig. 5A.—Theoretical Diagram of the Philco Transitone Model 6.

lack of selectivity and increased noise level will be noticed between 550 and 700 kilocycles. The secondary of this transformer is tuned by the first section of the 3-gang condenser. The trimming condenser is necessary in order to compensate for small variations in minimum capacity between this and the other two gang condenser sections.

The first 36 valve amplifies the extremely weak signals picked up by the aerial, and passes them on to the second 36 valve *viâ* the second R.F. transformer whose secondary is tuned to resonance with the incoming signal by the second section of the 3-gang condenser together with its trimming condenser. The valves and transformers are so well balanced that substantially uniform gain is obtained throughout the entire broadcast tuning range.

How Selectivity is Obtained

The first two transformers are tuned, as described, to the incoming signal which it is desired to receive, but so far, the circuits are not sufficiently selective to keep out adjacent broadcast transmissions, so additional tuned circuits are necessary. This could be accomplished by using many additional sections of variable condensers along with transformers, but it can be done very much better and more economically by using the superheterodyne principle.

The second 36 valve is therefore arranged to function both as a further amplifier of the incoming signal, and as an oscillator to generate the local oscillatory signal. The incoming frequency from the aerial circuits may be any frequency between 550 and 1,500 kilocycles (545 to 200 metres), and in this valve and its associated circuits this incoming signal is converted into a single predetermined frequency in order that it may be further amplified and segregated from all other frequencies by means of the sharply tuned, high gain intermediate - frequency transformers.

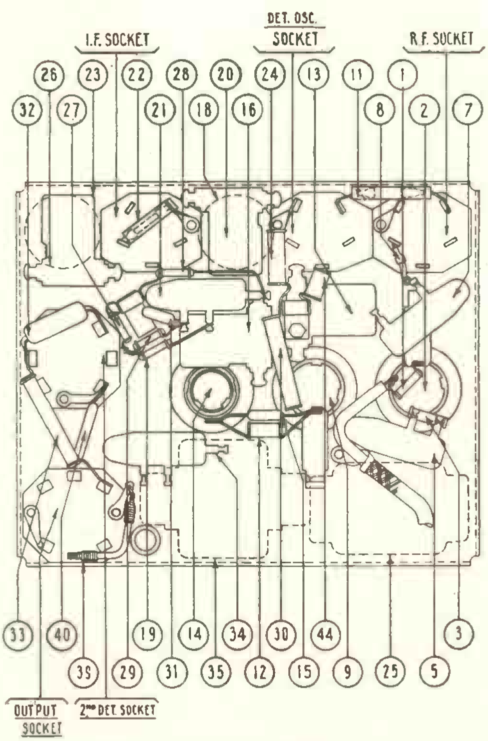


Fig. 5B.—The Layout of Components of the Model 6.

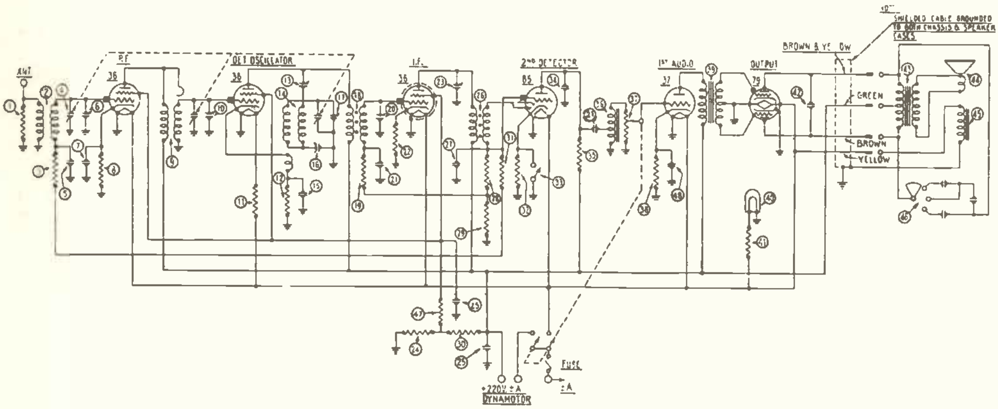


Fig. 6A.—THEORETICAL DIAGRAM OF THE PHILCO TRANSITONE MODELS 9 AND 12.

The Model 12 employs the circuit shown above with the exception that the valve heaters are series paralleled for 12 volt operation.

The Frequency Changer

The frequency conversion is effected as follows: Radio frequency oscillations of constant amplitude are generated by the second 36 valve, but at a frequency always 260 kilocycles higher than the incoming signal frequency. The third section of the gang condenser and its trimmers and the oscillator coil assembly maintain this difference in frequency at all positions of the tuning condenser throughout the broadcast band.

This difference in frequency, 260 kilocycles, is termed the intermediate frequency, and it is to this frequency to which the highly selective I.F. transformers are tuned by their trimming condensers.

The oscillatory frequency is mixed with the incoming signal frequency through the cathode earth-return circuit, this being a common path to both the incoming signal and the oscillator signal. Both exert their influence on the plate circuit of the valve, developing a 260 kilocycle signal which is "picked up" by the primary of the I.F. transformer which is tuned to this frequency.

The amplitude of this 260 kilocycle signal varies as a function of the degree of modulation of the incoming signal, and it therefore follows that the incoming signal which may be, as already stated, any frequency between 550 and 1,500 kilocycles, is effectively changed to a single predetermined frequency (260 kilocycles) which carries an exact replica of the modulation frequencies on the incoming signal.

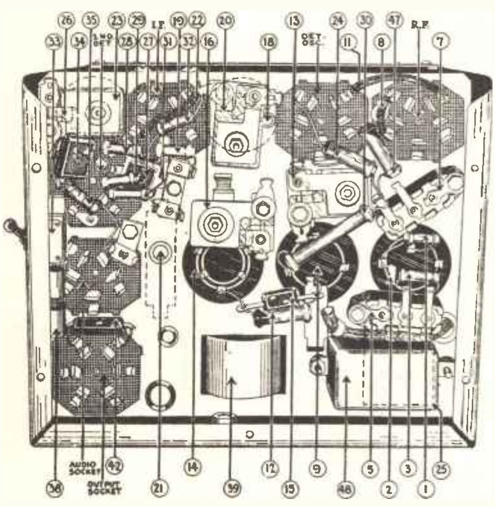


Fig. 6B.—THE LAYOUT OF COMPONENTS OF THE MODELS 9 AND 12.

The design of the oscillatory circuits is so carefully worked out that the gain effected in this stage remains constant for all broadcast frequencies.

The intermediate frequency amplifier stage now amplifies the 260 kilocycle signal in just the same manner as the first stage amplified the signal from the aerial. The I.F. amplifier valve is located inside the screen to the left of the oscillator valve in Fig. 3.

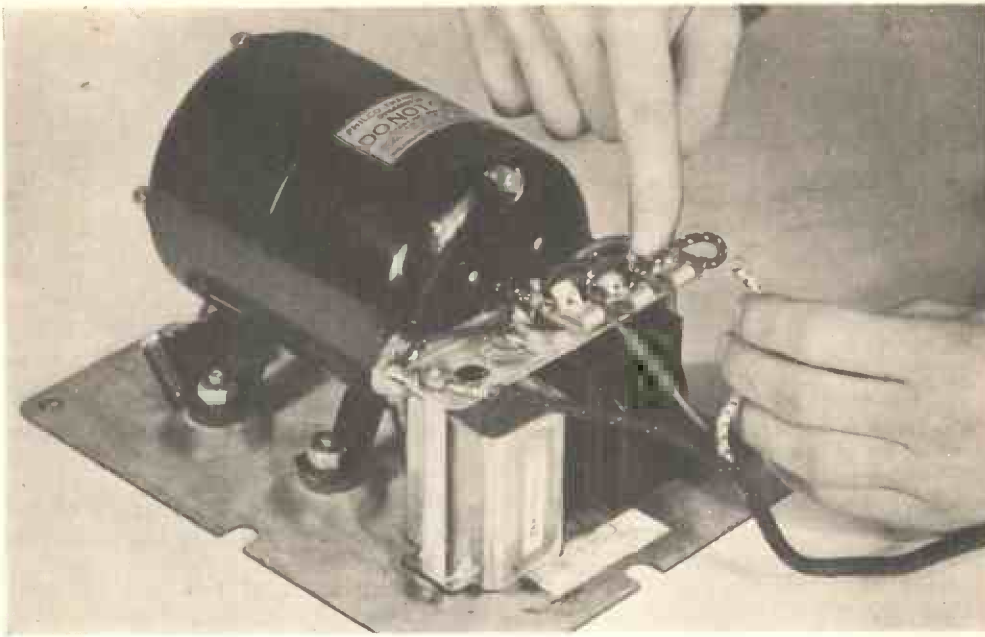


Fig. 7.—The Dynamotor Unit.

This unit takes its power from the 6 or 12 volt car starter battery and delivers 220 volts smoothed D.C. at 40 milliamperes at its output terminals, which is the normal maximum drain by the receiver. Observe the H.F. Choke under the H.T. output terminal: this prevents modulation hum. Fahenstock clip terminals are used in preference to screw terminals, as they always retain a more certain grip on the wire.

The bearings are so constructed that they never require oil, and as may be seen on the label, must not be oiled. Note the live rubber mounting to eliminate all possibility of mechanical noise.

The screen voltages are all properly adjusted by means of a resistor network, and an additional resistance capacity filter is used to prevent interference from stray external pick-up entering the receiver through these circuits.

A Recently Introduced Valve Development

Coupled by the second tuned I.F. transformer to the I.F. amplifier valve output is one of the comparatively new type 85 duo-diode-triode valves, developed as the result of the Transitone Research Laboratories' experience with the type 38 power pentode valve used as a diode detector/amplifier/A.V.C. valve in earlier Transitone receivers.

This valve is actually three valves in one, a three-electrode amplifying valve, a source of negative D.C. potential for automatic volume

Fig. 8.—The Loud Speaker Unit.

This shows the back of the moving-coil speaker used with the Models 9 and 12 Transitones. The felt ring acts as an effective dust seal, and yet prevents "box resonance." The knob on the side is a four-position tone control.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8–11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

CONSTRUCTION · EXPERIMENTAL · THEORY

NEWNES COMPLETE WIRELESS

In This Part

GLOSSARY OF TERMS

SYMBOLS USED IN WIRELESS DIAGRAMS

USEFUL TABLES AND CHARTS

INDEX

1/-

Part 32

THIS PART COMPLETES THE WORK

PART 32.

control, and the most efficient and consequently most distortionless detector known. All three elements operate on the one common cathode.

The A.V.C.

The secondary of the last I.F. transformer is connected to the diode elements of the 85 valve and to condenser 31 and resistors 27 and 29 (Fig. 5A). As the 260 k.c. signal is rectified in this circuit, D.C. flows through the two resistors and appears across the condenser as a negative potential which is directly proportional to the strength of the incoming signal.

Since the grid of the first (R.F.) 36 valve is connected through resistors 3 and 28 to the condenser 31, this negative potential is impressed on the grid of the valve, thereby controlling its effective amplification.

The effective amplification of the I.F. stage is controlled in the same manner, but only by a part of the rectified signal voltage (to avoid curvature rectification of the amplified signal) taken from the voltage divider circuit made up of resistors 29 and 27. Interaction between the various circuits through this A.V.C. network is prevented by filtration effected by resistor 19 and condenser 21 and by resistor 3 and condenser 5.

The circuit is so arranged and adjusted that the sensitivity of the receiver is automatically controlled to produce full-volume output irrespective of the strength of the received signal. If less than full volume output is required the volume may be controlled manually by the volume control knob on the tuning unit.

The "Local/ Distance" Switch

In the models 9 and 12

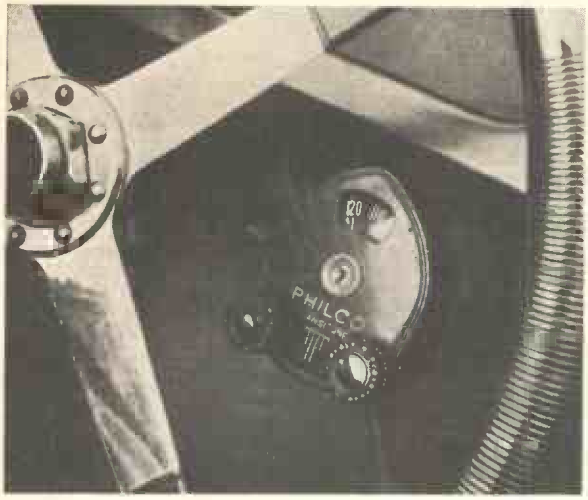


Fig. 9.—THE TUNING UNIT FITTED TO THE STEERING COLUMN OF A "BABY" FORD SPORTS CAR.

The dial is calibrated in tens-of-kilocycles and covers the wavelength range of 200 to 550 metres.

The left-hand knob is the on/off switch and volume control which may be locked in the "off" position by means of the Yale-type lock seen in the centre. The right-hand knob is the tuner. Ease of operation is ensured by the illuminated green figures on a black ground.

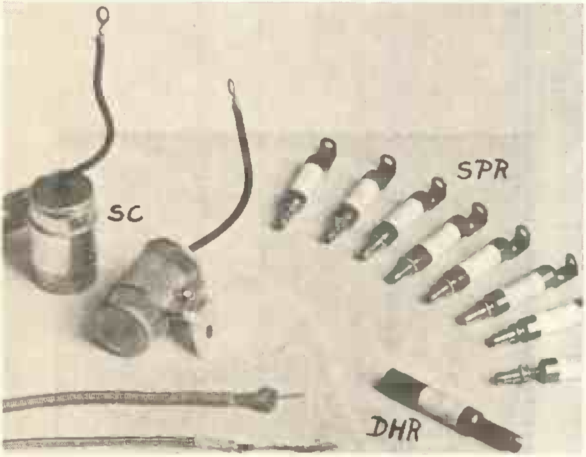


Fig. 10.—COMPONENT PARTS USED FOR SUPPRESSING INTERFERENCE FROM THE IGNITION AND CAR GENERATOR SYSTEMS.

One spark plug resistor, SPR, is fitted to each spark plug, and a special resistor, DHR, is fitted to the main feed of the distributor head.

Suppression condensers, SC, are fitted to the generator and the low-tension side of the ignition system.

The two lengths of wire shown are examples of the kind of shielded wire which is often necessary for the aerial down-lead.

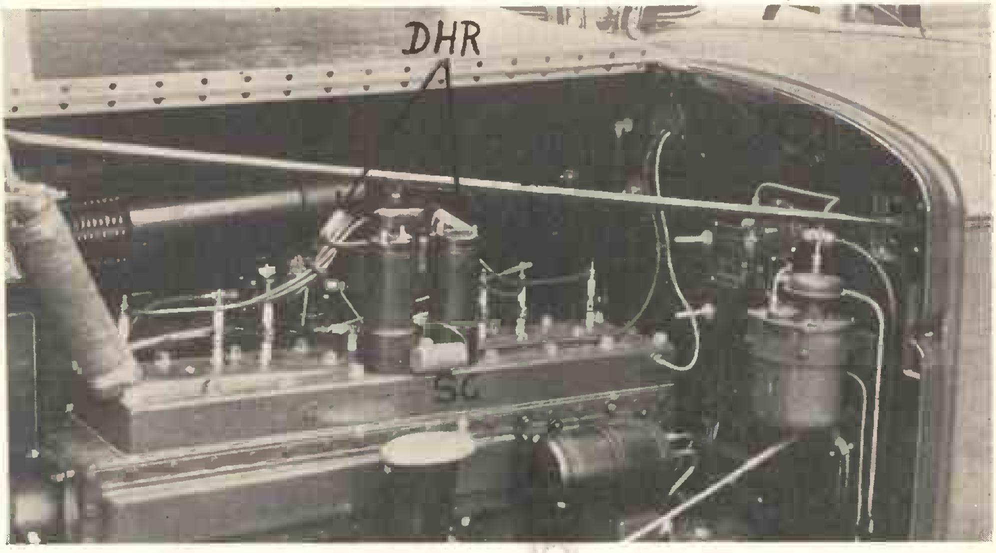


Fig. 11.—NOISE SUPPRESSION ON A PACKARD 8-CYLINDER ENGINE.

The spark plug resistors may be seen in place here, one on each of the eight plugs. Note the two resistors, DHR, suspended on the wiring by the distributor head. The standard resistor seen in Fig. 10 could not be used, so a special screw type resistor which suspends on the wire has to be used instead. Two are used because this car employs two coils. Note also the suppression condenser, SC, mounted on the base of the ignition coils. This connects to the battery side of the coil feed and by-passes interference which otherwise would reach the car lighting wires and the aerial.

(Fig. 6A) a resistor (32) is included in the cathode return circuit of the valve with a short-circuiting switch. This is the switch seen on the side of the receiver case, and is the local-distance switch.

When the switch is closed, the cathode is returned directly to earth, and the diodes will then rectify the smallest signal which may be received; this is the "Distance" position.

When the switch is opened, however, a voltage drop occurs across the resistor due to the steady anode current flow from the triode element. This potential, it will be seen, is applied as a bias to the diode elements with the result that signals of small intensity are not rectified, and not until a strong signal capable of creating a voltage *greater than the bias voltage* on the diodes is tuned in does rectification commence and create an audible signal to be passed on for final reproduction. An absolutely dead silent background is obtained in this manner, and renders pleasurable listening possible when passing under tramway wires or through areas notorious for local interference.

The output circuits of the Model 6, and of the Models 9 and 12, will be discussed separately as they are radically different.

Fig. 12.—A CLOSE-UP OF THE SCREW-TYPE DISTRIBUTOR HEAD INTERFERENCE SUPPRESSORS BEING FITTED TO THE WIRING OF THE ENGINE SEEN IN FIG. 11.

The Model 6 Output Circuit

Following the type 85 Duo-diode-triode valve in the Model 6 set is a parallel fed auto-transformer. Parallel feed is used in order to retain the same high quality of reproduction on both strong and weak stations. The A.C. *impedance* of a resistance is quite independent of the degree of direct current which may be flowing through it. If the auto-transformer were included directly in the triode-anode circuit of the 85 valve, attenuation of the lower musical frequencies would take place with weak signals, due to the reduction of the effective inductance of the primary winding. This would be caused by the considerable anode current flow (9 m.a. approximately) of the triode element of the 85 valve, due to the fact that the grid-bias of the triode element is provided by, and is directly proportional to the rectified signal from the diodes. At no-signal the triode grid bias is therefore zero.

The Philco type 85 valve is very carefully designed so that the voltage generated by a normal maximum R.F. signal biases the triode element in such a manner that it may handle the rectified signal carrying 100 per cent. modulation *without curvature distortion*. It will be appreciated also that it is impossible for the grid of the triode element to ever become positive, so that *amplitude distortion* due to the flow of grid current will never take place.

The Auto-Transformer

The auto-transformer 35 steps-up the signal output of the 85 valve and delivers it to the control grid of the type 41 valve. This type 41 is a pentode output valve specially developed for automobile operation, and delivers 1·6 watts undistorted output to the voice coil of the moving coil speaker *viâ* the conventional direct feed output transformer 41.

The Moving Coil Speaker Unit

The moving coil speaker, as with the other units, is fitted inside a pressed steel housing. The front of this is covered with steel wire mesh to prevent damage to the diaphragm by the front car passenger—the speaker normally being mounted under the left side of the car instrument panel over the passenger's feet. This steel grille is backed by layers of open-mesh doped cotton to prevent dust and dirt reaching the speaker voice-coil gap.

The field coil is energised from the car starter battery in order that a constant, strong magnetic flux may always be present.

The Aerial

The aerial usually consists of a sheet of copper mesh or poultry wire fitted under a false headlining in the roof of a saloon car, or it may consist of a length of wire woven into a similar false headlining under the hood of a touring car, or again, it may be a length of wire run backwards and forwards under the upholstery of the back seat in cars where a roof-top aerial is impracticable. The car chassis forms the earth.

The aerial lead-down generally requires to be screened if it passes near the engine compartment or near any of the car lighting wires; two suitable forms of screened wire are shown, the larger to be used wherever possible, but appearance very often demands the thinner wire, which is more easily concealed.

An open aerial depends for its efficiency on the impedance of the earth immediately beneath it, and only to a secondary extent on the surrounding earth; therefore there is no object whatever in attempting to obtain contact with the earth beneath the car by means of trailing chains or similar means, as the effective height of the aerial is in no way improved by so doing, and no advantage is gained.

Also, the erratic contact which such a trailing earth would make with the ground will create a great deal of interference in the receiver.

The Earth

The earth is the most important part of the receiver, and consequently all parts of the metal body and the chassis and engine must be carefully bonded together, otherwise potential differences will occur which may modulate an incoming signal with crackling noises; or rustling and crackling noises may be heard whilst travelling due to, say, a part of the body making erratic contact with the chassis.

WIRELESS MATHEMATICS MADE INTERESTING

By W. F. FLOYD, B.Sc. (Lond.)

SECTION XV—SOME AIDS TO CALCULATION IN DESIGN PROBLEMS

Frequency—Wavelength Conversion

WHEN dealing with tuned circuits it is frequently necessary to convert a frequency reading into a wavelength, or *vice versâ*, and this can be done by means of the chart in Fig. 1. It will be seen that there are three frequency and three wavelength scales, to cover the range of wavelengths from 3 to 3,000 metres in three steps. As an example, let us find the frequency corresponding to a wavelength of 75 metres. This wavelength lies in range 2 on the wavelength scale and the point P on the graph corresponds to it. Referring to range 2 along the frequency scale we see that P corresponds to a frequency of 4 megacycles per second (mc/s.)—*i.e.*, a frequency of 4 million c/s. We have thus converted from a *wavelength* of 75 metres to a *frequency* of 4 mc/s.

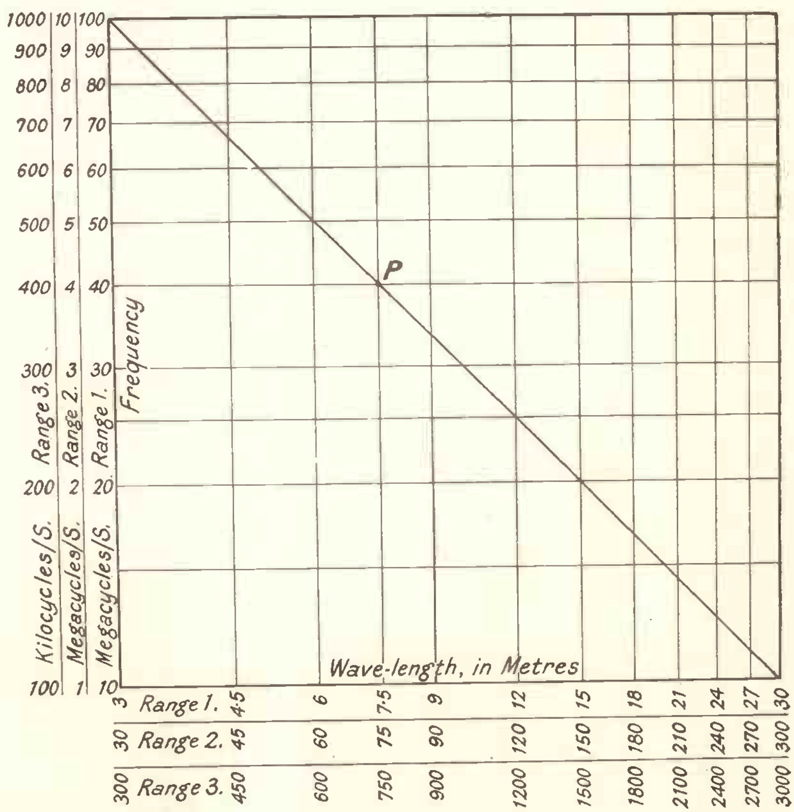


Fig. 1.—Chart for Converting from Frequency to Wavelength, and Vice Versâ.

It will be clear that we may extend both scales by multiplying or dividing the ranges by 10 for any desired number of times. Thus, a wavelength of 0·75 metres (*i.e.*, 75 metres ÷ 100) corresponds to a frequency of 400 mc/s. (*i.e.*, 4 mc/s. × 100), and a wavelength of 0·075 metres (*i.e.*,

TABLE I.

Showing Nagaoka's Factor, K, *and the Shape Factor,* S, *for Inductance Calculations.*

$\frac{d}{l}$	K	S	$\frac{d}{l}$	K	S
0·0	1·0	inf.	1·9	·54	0·28
0·1	·96	9·6	2·0	·53	0·27
0·2	·92	4·6	2·5	·47	0·19
0·3	·88	2·9	3·0	·43	0·14
0·4	·85	2·1	3·5	·39	0·11
0·5	·82	1·6	4·0	·37	0·091
0·6	·79	1·3	4·5	·34	0·076
0·7	·76	1·1	5·0	·32	0·064
0·8	·74	0·92	6·0	·29	0·048
0·9	·71	0·78	7·0	·26	0·037
1·0	·69	0·69	8·0	·24	0·030
1·1	·67	0·60	9·0	·22	0·024
1·2	·65	0·54	10·0	·20	0·020
1·3	·63	0·48	15·0	·15	0·010
1·4	·61	0·44	20·0	·12	0·0062
1·5	·60	0·40	30·0	·091	0·0030
1·6	·58	0·36	40·0	·073	0·0018
1·7	·56	0·33	50·0	·061	0·0012
1·8	·55	0·31	100·0	·035	0·00035

TABLE II.

Showing the Inductance of Single Layer Coils, of Circular Section wound with 40 *Turns of Wire per inch. The Inductance Values are given in Microhenries (mH.).*

Length in Inches.	Diameter in Inches.									
	d = 1·0.	1·5.	2·0.	2·5.	3·0.	3·5.	4·0.	4·5.	5·0.	6·0.
l=1·0	27·5	53·5	84·0	118·0	154·5	193·0	234·0	276·0	320·0	411·5
1·5	46·0	93·0	150·0	214·0	284·0	359·0	440·0	521·0	606·5	790·0
2·0	65·5	134·5	220·0	319·0	428·0	547·0	672·5	803·0	943·0	1235
2·5	85·0	177·5	294·0	430·0	583·0	748·0	927·0	1115	1314	1731
3·0	104·5	221·0	369·5	545·0	743·0	963·0	1200	1444	1712	2270
3·5	124·5	264·5	446·0	662·0	908·0	1180	1475	1790	2124	2838
4·0	144·0	309·0	523·5	781·0	1076	1404	1763	2144	2552	3426
4·5	164·0	353·5	602·0	902·0	1253	1633	2052	2506	2994	4040
5·0	184·0	397·0	680·0	1023	1419	1862	2350	2876	3440	4665
6·0	223·5	486·0	837·0	1267	1768	2330	2954	3633	4360	5945

75 m. ÷ 1,000) to a frequency of 4,000 mc/s. (*i.e.*, 4 mc/s. × 1,000). These are extremely short waves, and are not met very frequently in radio work outside a laboratory, but the examples serve to illustrate the universal nature of the conversion chart.

THE CALCULATION OF INDUCTANCE

We dealt with inductance calculation and design in some detail in sections V. and X., and it will suffice for our present purpose if we reproduce here only the formulæ we employed; readers who need to revise their knowledge of the use of the formulæ should refer to these sections. For a single layer coil, of circular cross section, the inductance is :—

$$L = 0{\cdot}02505 \times d^2n^2lK \ (mH.)$$

where
d = diameter of coil in inches.
n = number of turns of wire per inch.
l = length of winding in inches,
and
K = Nagaoka's Factor, which depends on the ratio of d to l and is given in Table I. This table is more detailed than that given in Section V. and hence can be used to cover almost all shapes of coils.

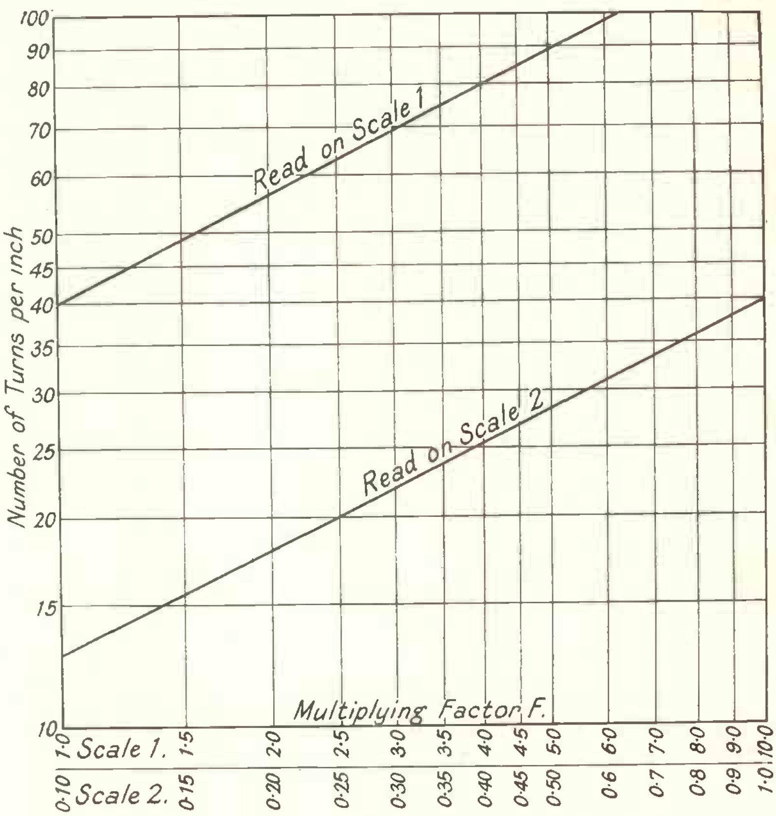


Fig. 2.—Graph giving Value of Multiplying Factor (F) for use with Table of Inductance of Single Layer Coils of Circular Section.

An Alternative Formula

An alternative formula to the above is the following :—

$$L = 0{\cdot}02505 \times d^3n^2S \qquad (mH.)$$

where S is a Shape Factor and is also given in the table. It will be recalled that this formula must be employed when the inductance value is known, and it is desired to calculate the size and shape of the coil to give that particular inductance value. Examples will be found in Section X.

Inductance of Single Layer Coils

In order to restrict the use of the formulæ to cases where the dimensions are not exact multiples of half an inch, Table II. has been compiled. This gives, at a glance, the inductance of single layer coils of circular section with diameter and winding length within the ranges shown. The table is only correct, however, for coils wound with 40 turns of wire per inch. When the pitch of the winding is other than 40 turns per inch the inductance value given by the Table must be multi-

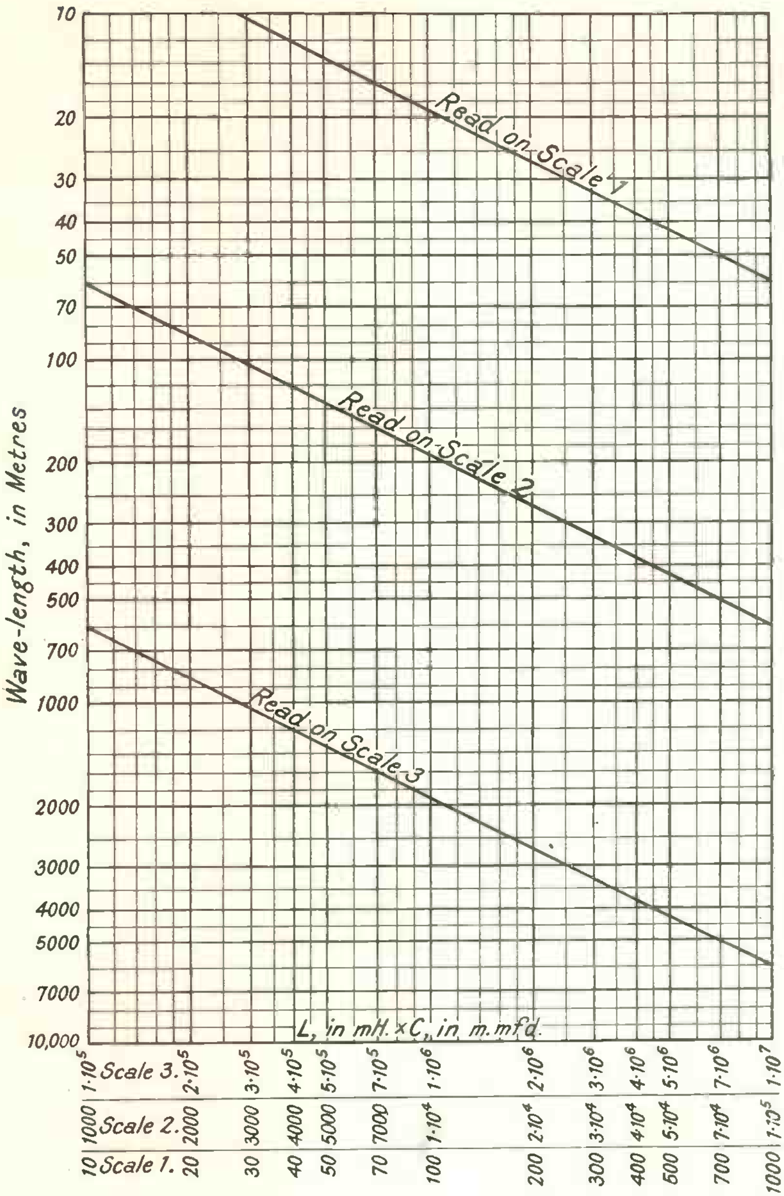


Fig. 3.—Graph giving L.C. Value corresponding to Wavelengths from 10 to 10,000 Metres.

plied by a correcting factor, which can be read on the graph of Fig. 2. That is to say, if the required inductance value is L, and if the inductance value, corresponding to the coil dimensions and read from Table II., is L_0, then :—

$$L = L_0 \times F,$$

where F is the Multiplying Factor obtained from Fig. 2.

An Example

As an example, suppose that we require the inductance of a coil of diameter 3·5 inches and length 3·0 inches, wound with 50 turns per inch. From Table II. the L_0 inductance value is 963 mH., and from Fig. 2 the multiplying factor, F, is 1·6, approximately, the more accurate figure is 1·57. Thus the required inductance value, L, is 963 × 1·6, *i.e.*, 1541 mH. approximately.

The more accurately the value of F can be obtained from Fig. 2, the more accurate is the ultimate inductance value. In the above example the accuracy is of the order of 2 per cent. Had we taken the more exact value for F, viz., 1·57, our answer would have been as accurate as the L_0 value obtained from Table II. The accuracy of the table is of the order of 0·2 per cent.

WAVELENGTH AND LC VALUE

We have seen that the wavelength to which a tuned circuit resonates depends on the values of inductance and capacity employed, and we derived the formula :—

$$\lambda = 1885 \sqrt{LC}$$
(metres)

where

λ = wavelength in metres,

L = inductance in micro-henries, and

C = capacity in microfarads.

The graph of Fig. 3 gives the LC value corresponding to wavelengths from 10 to 10,000 metres, and hence its use abolishes calculations with the above formula. For convenience of manipulation of figures the capacity has been expressed in micro-microfarads (m.mfd.) instead of in microfarads, as in the formula. The chart may be employed either to predict the wavelength to which a particular combination of inductance and capacity will tune, or to determine the value of inductance or capacity required to tune to any particular wavelength.

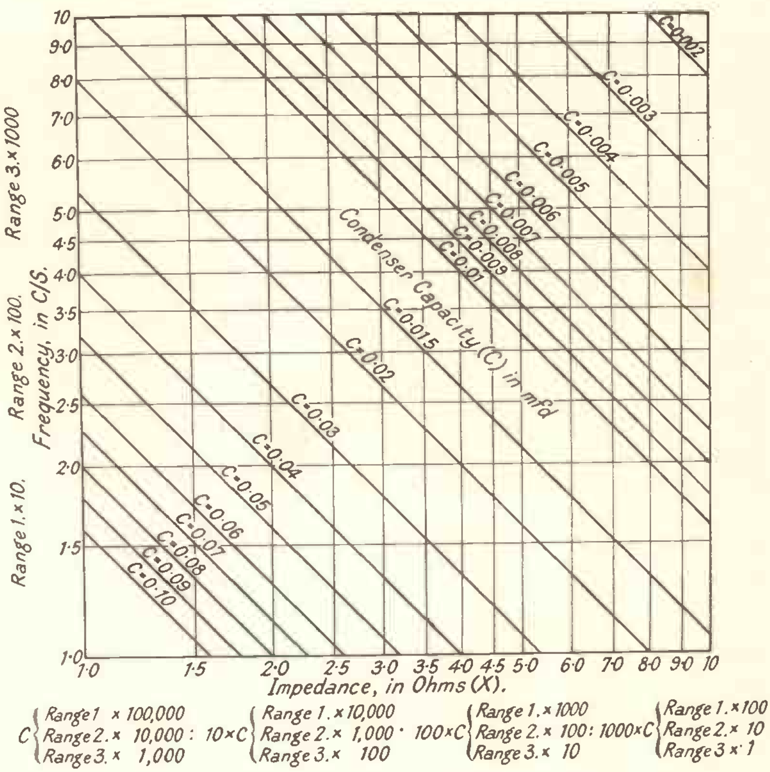


Fig. 4.—Graph giving Condenser Impedance at Audio Frequencies.

An Example

Suppose that we have an inductance of 1,200 mH. tuned by a condenser of maximum capacity 500 m.mfd. (*i.e.*, 0·0005 mfd.). The LC product is 1200×500, *i.e.*, 6×10^5, and as this value occurs along scale 3 we must read the corresponding wavelength from the line labelled " read on scale 3." Doing this, we find the wavelength required is approximately 1,445 metres.

Suppose, now, that we need a circuit which will tune to 50 metres. From the graph we see that the required LC value must be read from scale 1, and is, in fact, 700. As we are concerned with a short wavelength, we should employ a condenser with a maximum capacity of not more than 100 m.mfd., and taking this value we see that an inductance of $700 \div 100$ mH., *i.e.*, 7 mH., must be employed. The dimensions of the coil can be found, approximately, by means of the inductance formula quoted previously, but the value so obtained is only approximate for the reasons given in Section X., where we dealt with inductance calculations on short waves.

CONDENSER IMPEDANCE

The chart in Fig. 4 gives the impedance (X), in ohms, of a condenser at audio frequencies, the frequency range covered being from 10 to 10,000 c/s. The condenser values range from 0·002 mfd. to 0·1 mfd. These values can be multiplied by 10, 100, and by 1,000 if necessary, and in all four cases, *i.e.*, 1 × C, 10 × C, 100 × C, and 1,000 × C—the appropriate impedance range is indicated on the chart.

An Example

Let us find the impedance of a condenser of capacity 0·02 mfd. at a frequency of 4,500 c/s. Range 3 on the frequency scale gives us a frequency of 4,500 c/s, and we find that C = 0·02 mfd. crosses the 4,500 c/s frequency line at a value of 1·8 on the impedance scale. We have taken the 1 × C condenser range and range 3 on the frequency scale, and hence we read the impedance on " C, range 3 " which gives the actual impedance as 1·8 × 1,000 ohms, *i.e.*, 1,800 ohms.

Another Example

As a further example, let us find the impedance offered by a capacity 4·0 mfd. at a frequency of 250 c/s. We can obtain 4·0 mfd. by multiplying 0·04 mfd. by 100. Also, 250 c/s is on range 2 of the frequency scale, hence we read the impedance on range "100 × C, range 2." That is to say, the impedance is 1·6 × 100 ohms, *i.e.*, 160 ohms.

GRID LEAK AND CONDENSER COUPLING EFFICIENCY

The efficiency of R.C. coupling in an audio frequency amplifying stage varies with the frequency and with the relative values of condenser capacity and leak resistance. In Fig. 5, *e* is the voltage developed across the leak, R, when a voltage, E, is applied across the coupling, R plus C. The efficiency of the coupling is the value of the ratio *e*/E.

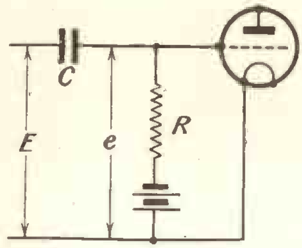


Fig. 5.—The Efficiency of R.C. Coupling.

The curves in Fig. 6 have been drawn to show the coupling efficiency for various values of the ratio of condenser impedance (X) to leak resistance (R). The condenser impedance is obtained from the chart in Fig. 4, and dividing the value so obtained by the resistance, in ohms, of the leak, the value of X/R is obtained. The efficiency can then be read from the curves of Fig. 6. For any particular combination of condenser and leak the efficiency at various frequencies can be found, and a curve drawn showing the extent of frequency distortion in the amplifier due to the coupling.

It is clear from Fig. 6 that the smaller the ratio of X to R, the greater the efficiency. That is to say, with a particular value of leak, the smaller the condenser impedance, the greater the efficiency. Condenser impedance varies with frequency, and the larger the condenser the less its impedance at any one frequency. Therefore, the larger the value of C in Fig. 5 the more efficient the coupling. The objection to making C very large is that the grid then becomes blocked by the large charge, accumulating

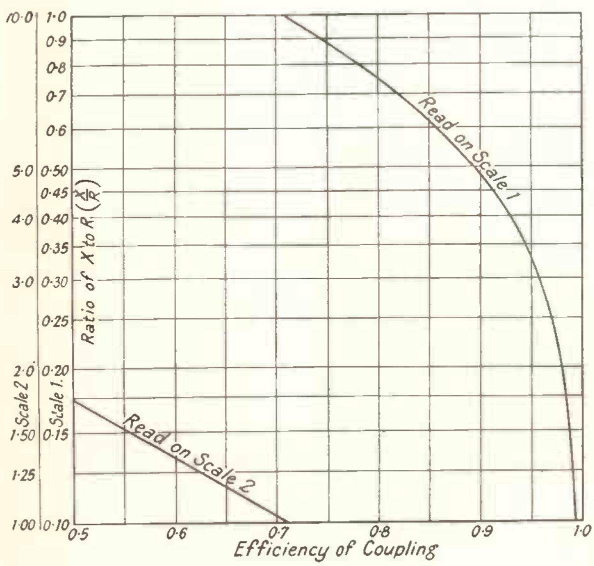


Fig. 6.—Graph showing Efficiency of Grid Leak and Condenser Coupling Circuit for Different Ratios of Condenser Impedance (X) to Resistance (R).

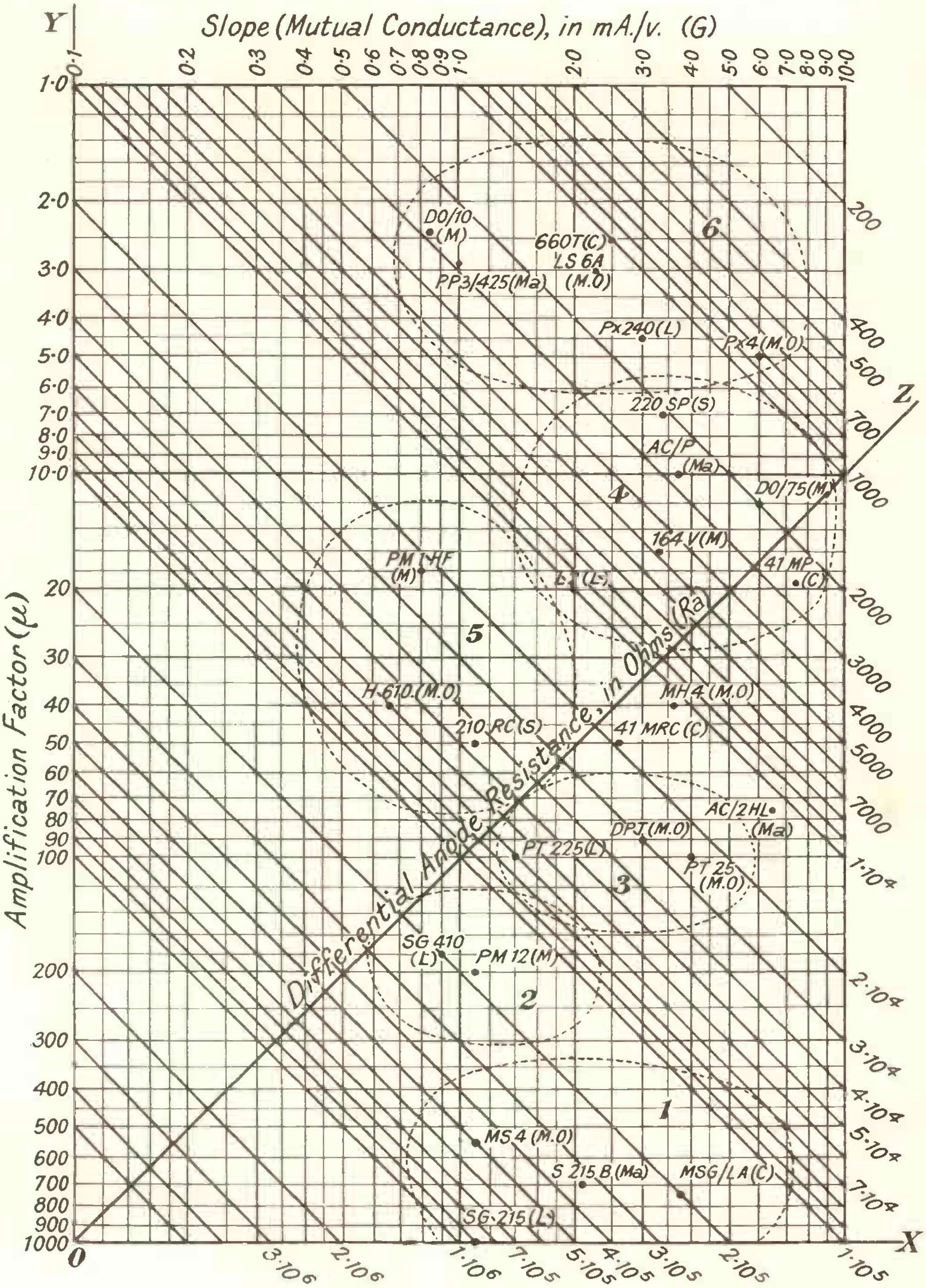


Fig. 7.—Valve Data Chart.

Dotted region No. 1, indicates grouping of SG mains valves; 2, SG battery valves; 3, pentode valves; 4. power valves; 5, general purpose valves; 6, super-power valves.

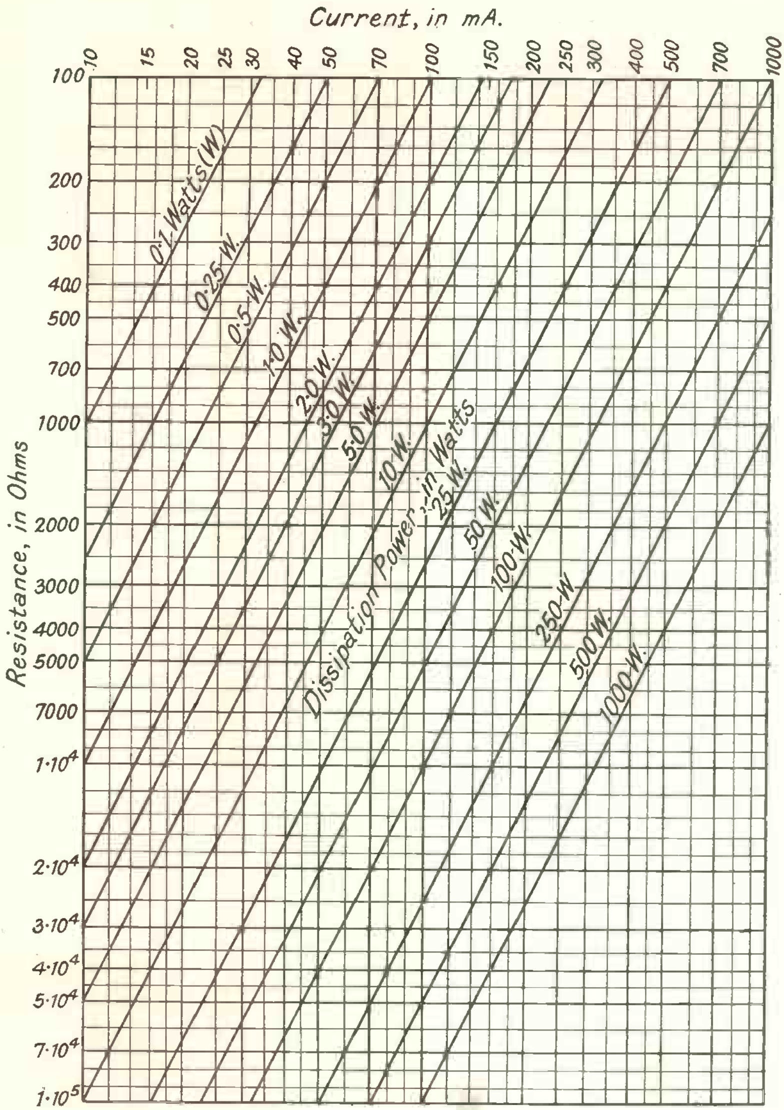


Fig. 8.—Chart showing Power dissipated in a Resistance carrying Direct Current.

on C, which is unable to leak away quickly enough to follow the audio frequency voltage variations due to the signal.

An Example

As an example, take the case of a capacity of 0·01 and a leak of 0·25 megohm. At a frequency of 50 c/s. the impedance of the condenser is found to be 320,000 ohms. Thus, the ratio X/R is 320,000/250,000, *i.e.*, 1·28. The efficiency corresponding to this is found from scale 2, and is 0·615, or 61·5 per cent. By employing a leak of resistance 1·0 megohms the efficiency can be raised to 0·905, or 90·5 per cent.

At a frequency of 500 c/s, when the condenser impedance becomes only 32,000 ohms, these figures become 0·99 and 0·995, respectively, *i.e.*, 99 and 99·5 per cent.

VALVE DATA CHART

The chart of Fig. 7 is an extremely useful form of chart, for it enables the user to see at a glance how accurately one valve is matched to another. Further, when a valve is required, possessing a particular set of characteristics, the chart shows which maker's valve, and its type number, comes nearest to the prescribed characteristics. As shown in Fig. 7, the chart is incomplete, only a selection of valves having been plotted. The reader who constructs his own chart on these lines should have no difficulty in making an exact copy. The graph paper required is one sheet having 2 × log scale along one axis and 3 × log scale along the other. The diagonal scale must be drawn in by hand. Every point on the chart corresponds to one particular set of characteristics only. That is to say, every point corresponds to one value along each of the three axes OX, OY, and OZ, *i.e.*, to one value of S, M, and R_a.

An Example

Suppose that we require a screened grid valve with as large a slope as possible, but with an anode impedance (R_a) not greater than 400,000 (*i.e.*, 4×10^5) ohms. On the chart we see that there are two valves to choose from, viz., the S 215B (Ma) and the MSG/LA (C). There are several other valves available but, as stated previously, these are not plotted. The letters in brackets after the valves indicate the maker, the following being the key :—

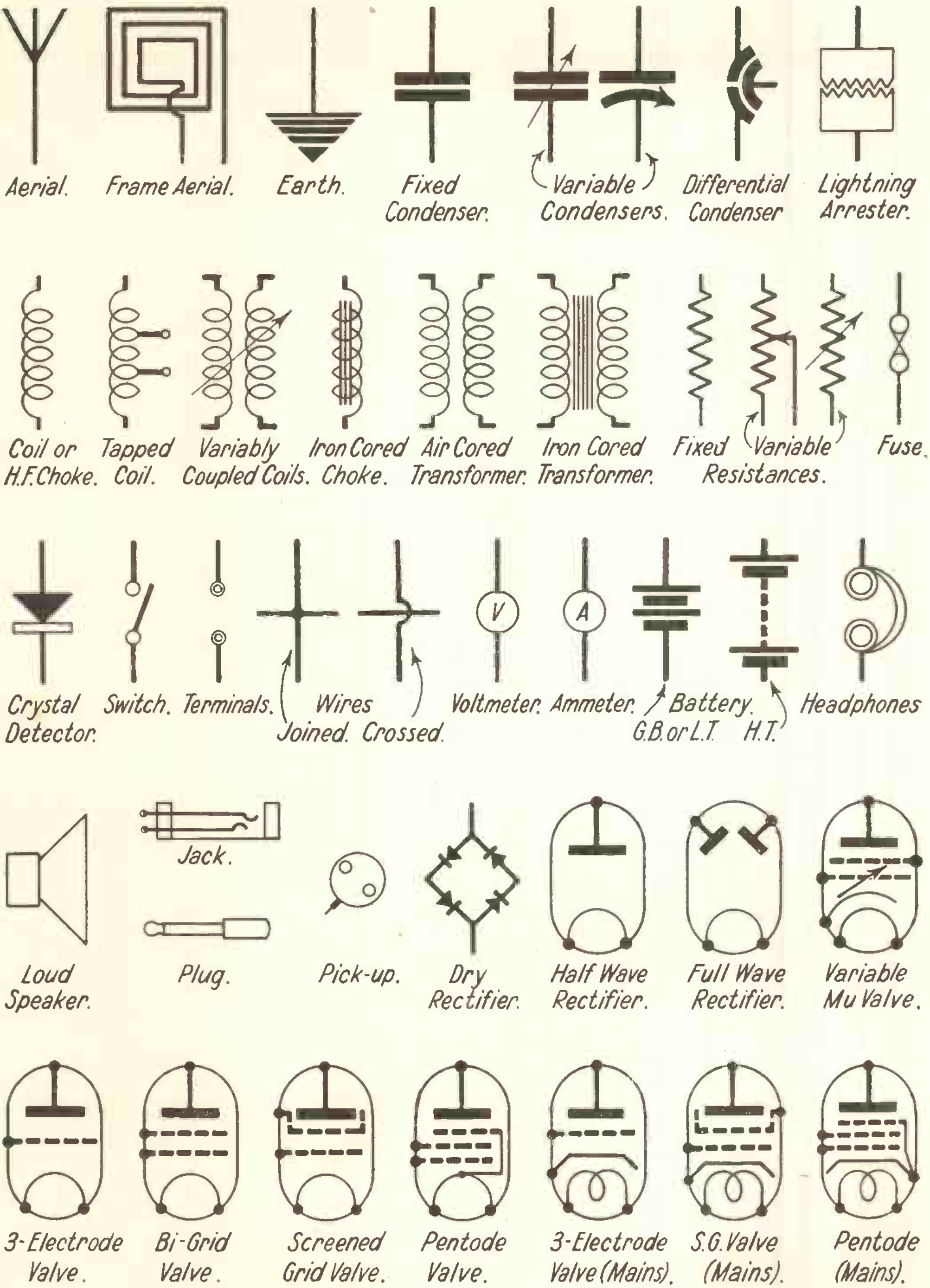
C = Cossor.
L = Lissen.
Ma = Mazda.
M.O = Marconi and Osram.
M = Mullard.
S = Six-sixty.

POWER DISSIPATION CHART FOR A RESISTANCE CARRYING A DIRECT CURRENT

Much valuable time is saved by the use of the chart in Fig. 8 which gives the power dissipated in a resistance carrying direct current. The current values are given in millliamps., and range from 10 to 1,000 milliamperes ; the resistance values range from 100 to 100,000 ohms ; the power dissipation range is from 0·1 watts to 1,000 watts. These ranges cover practically all the cases met with in radio work, from the small powers dissipated in grid leaks carrying grid current, and anode resistances carrying anode current, up to the large powers in resistances and resistance lamps used in D.C. mains operated instruments and for accumulator charging.

The chart enables the user to determine what capacity resistance is required for any specific purpose, and also serves as a guide to indicate what amount of cooling will be required, *i.e.*, whether much or little heat is generated. Thus, suppose that we require a 4,000 ohms resistance to carry a current of 25 milliamperes. We see that the power dissipated is greater than 2 watts but less than 3 watts. Hence, a 3 watt size resistance is suitable and will allow a slight overload of current before the saturation value is reached. The cooling required for this small power is not more than is usually found in a receiver. On the other hand, suppose that we propose to employ a 500 ohm resistance carrying a current of $\frac{1}{4}$ amp. (*i.e.*, 250 milliamperes) for accumulator charging, then we see that the power dissipated is between 25 and 50 watts. Considerable cooling must be provided in this case to dispose of the heat generated.

SYMBOLS USED IN WIRELESS DIAGRAMS



GLOSSARY OF TERMS

By RALPH STRANGER

A

"A" Battery.—American name for L.T. battery.

Absolute Units.—These are the units of measurement derived from the fundamental units of the C.G.S. system. C.G.S. stands for centimetre, gramme, second.

Absolute Zero.—This is − 273 degrees below zero on the Centigrade scale. The nearest approach to this temperature has been made by Professor Keesom, of Leyden University, viz., − 272·18 degrees.

Absorption.—A term applied to dissipation of energy in dielectric which results in delay of charging and discharging of a condenser in the initial stages.

Absorption Control.—A method of control of high-frequency oscillations in a transmitting aerial circuit, causing variations of amplitude at low frequency. The transmitting valve is made to absorb part of the energy.

Absorption Wavemeter.—A simple form of wavemeter, consisting of a coil and a variable condenser in parallel. The wavemeter, when tuned in resonance with the source of oscillations, absorbs most of the energy and stops the oscillations, thus indicating the wavelength to which it is tuned.

A.C.—Abbreviation of alternating current.

A.C. Component.—A term used in connection with the current in the valve anode circuit. The anode current is considered to be made up of three component currents: 1, the direct component which is the direct current flowing through the valve before the latter is connected to the aerial; 2, the alternating component which is the high-frequency current. It is not really an alternating current at all, but a high-frequency unidirectional pulsating component which has the same effect upon an inductance as a similar alternating current. No alternating current can pass through a valve, as the latter is a unidirectional device, passing the current from the filament to the anode; 3, the low-frequency component which is the cumulative result of the modulated high-frequency current, and is of the same form as the microphone current.

A.C. Mains.—Power station supply mains delivering an alternating current.

A C. Mains Charging.—Charging accumulators from A.C. mains with the help of a suitable step-down transformer and rectifier.

A.C. Mains Receiver.—A wireless receiver working from A.C. mains.

A.C. Resistance.—The effective resistance of a circuit to the flow of alternating current.

A.C. Valve.—A valve, the filament of which is designed to be heated direct from alternating mains without previous rectification.

Acceleration.—The rate of increase of velocity measured in feet per second per second. The reason for this double use of time is that velocity is the rate of change of length per second, and the rate of change o f velocity must be measured per second per second. Acceleration can also be expressed as the ratio $\frac{\text{Force}}{\text{Mass}}$.

Acceptor Circuit.—A tuning circuit consisting of a variable or fixed condenser in series with a coil. When tuned to a given wavelength (frequency) it will offer the current of this frequency a comparatively small resistance, while stopping currents of all other frequencies by offering them a large resistance.

Accumulator.—A secondary cell or a group of cells which have to be first charged by passing for some time a direct current through the accumulator, so as to effect certain chemical changes in the state of the plates, which are usually of lead, before a current can be taken from it.

Accumulator Capacity.—This should not be confused with the capacity of charged bodies. Accumulator capacity means the ability of the cells to deliver a current of a given strength for a definite period of time. It is also referred to as the ampere-hour capacity. There are two kinds of ampere-hour capacity: (1) the capacity for continuous discharge; (2) the capacity for intermittent discharge, as in the case of motor-car batteries. The intermittent discharge capacity is usually twice that of the continuous discharge capacity.

Acidometer.—Another name for a hydrometer which is used for measuring the specific gravity of accumulator acid.

Acoustics.—The science of sound.

Acoustic Waves.—Sound waves in air which consist of periodic rarefactions and compressions of air molecules. Sound waves can also be created in liquids and solids. The speed with which these waves travel depends upon the density and the elasticity of the medium in which they are being propagated. The speed of sound waves in air at the temperature of 0 degrees Centigrade and at 30 inches of mercury atmospheric pressure is 1,090 feet per second.

Adaptor.—A device which may be a component or a complete unit which, when added to an existing accessory or set, enables it to perform additional duties. Thus, we have valve adaptors, which enable further connections to be made, switch adaptors which allow two or more instruments to be connected to an existing mains' point, or short-wave adaptors which convert a receiver working on medium waves to receive short-wave transmissions.

Admiralty Unit.—This is a unit for measuring electrostatic capacity. It is called a jar. One jar equals 0·0011 microfarads.

Admittance.—The admittance of a circuit in which an alternating current is flowing is the reciprocal of the impedance:

$$\text{Admittance} = \frac{1}{\text{impedance}}.$$

It is measured in units called mhos (the word ohm reversed).

Aerial.—A conductor used for the purpose of intercepting electro-magnetic waves. This can be an elevated wire insulated from earth, an insulated wire erected inside the house, or an insulated wire wound on a frame.

Aerial Circuit.—The circuit connected between aerial and earth. It is also referred to as the tuning circuit.

Aerial Insulation.—Isolation of the aerial wire from supports, *i.e.*, from direct contact with the ground (earth).

Aerial Insulators.—Porcelain, glass, china or rubber accessories of various shapes placed between the aerial wire and the supports.

Aerial Resistance.—The resistance of the aerial wire to the passage of high-frequency oscillating currents. It is made up of radiation resistance, resistance due to the dielectric, and the ordinary resistance of the wire to the passage of a direct current.

Aerial Tuning Circuit.—This is usually a combination of a coil or coils and a variable condenser. There may be a single circuit or a loosely coupled aerial circuit. In the latter case we have two sets of coils and variable condensers, the coils being placed close to each other, and with or without direct electrical connection.

Aerial Tuning Condenser.—A variable condenser either in series with the aerial or in parallel with the aerial coil.

Aerial Tuning Inductance.—The coil connected between the aerial and earth can be of a variable type. Thus, we may have a coil with a slider which taps off the turns, or we may have a coil with a number of tappings connected to studs of a switch. It is also possible to have two coils in the form of a variometer, *i.e.*, one coil rotating inside the other.

Æther.—(See Ether.)

Air Condenser.—As a rule a condenser has some sort of insulating substance between its vanes, and this insulation is referred to as *dielectric*. Most of the variable condensers used for receiving circuits have *air dielectric*, *i.e.*, there is no insulation between the plates except the naturally present air. Air, when dry, is a good insulator.

Air-Core Choke.—This is a component which is often used in a wireless circuit. It consists of a coil wound on a cardboard, wooden, or ebonite former. Inside the coil there is no iron present in the form of a core, and this is the reason why the choke is called an air-core choke. The air-core choke is mostly used in high-frequency circuits.

Air-Core Transformer.—A transformer consists of two windings, primary and secondary, which may be mounted on an iron core (for low-frequency circuits), or a wooden, or ebonite former, in which case the "core" is air, and this type of transformer is used in high-frequency circuits.

Air-Gap.—This is the space between the magnet pole's surface and the surface of the armature in a dynamo, an electric motor, an alternator, or some similar electric machine. The space between pole pieces of an electro-magnet.

Air Line.—A telegraph or a telephone line of bare (uninsulated) wire supported on insulators mounted on poles. In the Army under field conditions an air line is often erected with insulated wire mounted on any elevated points without insulators.

Alternating Current.—An electrical current which periodically varies in magnitude and direction. It starts from zero, gradually but quickly increases to a certain maximum, then diminishes to zero. After that, it grows to a maximum in the reverse direction and drops down to zero again. The above represents a complete cycle of changes. An alternating current may reverse its direction 25, 40, 50 times per second in the case of industrial supply and as many as a million times a second and more in the case of radio circuits, and for this reason is called *high-frequency current.* Thus, when we talk about alternating currents, we mean moderate frequencies below 100 cycles, while higher frequencies of the order of thousands of cycles imply oscillating currents (very rapidly alternating currents).

Alternation.—Half a cycle.

Alternator.—An electrical generator of an alternating E.M.F. It consists of a magnet system and an armature carrying conductors which are connected to slip rings.

Aluminium Rectifier.—An electrolytic rectifier, *i.e.*, a device for converting an alternating current into a direct one, thanks to its unidirectional conductivity, the cathode (negative side) of which is made of aluminium.

Ammeter (Amperemeter).—An instrument for measuring the strength of electrical currents in amperes.

Amperage.—A somewhat clumsy term used by engineers for denoting the strength of current in amperes. A redundant term, imitating the word voltage.

Ampere.—A unit for measuring current. From the quantitative point of view, it is equivalent to 1 coulomb per second. It is equal to 6,000,000,000,000,000,000 electrons passing a point of the conductor per second.

The *international ampere* is the current which deposits 1·118 milligrammes of silver per second when passing through a solution of silver nitrate.

The *legal ampere* is the current which gives a certain reading on a standard ampere balance kept at the offices of the Board of Trade.

Ampère, André Marie.—French scientist born 1775, died 1836. Well known for his work in electricity and magnetism. The unit of current is named after him.

Ampere-Hour.—This is a unit of quantity of electricity used commercially. The term ampere-hour means a quantity of electricity used up in some way or other when an ampere of current has been flowing for an hour. In the case of, say, a 40 ampere-hour accumulator, the term denotes that the accumulator will give out 1 ampere for forty hours, or ½ ampere for eighty hours, or ¼ ampere for 160 hours, and so on.

Ampere-Turns.—A term meaning the product of current in amperes and the number of turns in the coil through which this current is flowing. Thus, in assessing the magneto-motive force produced by such a coil, we use the formula M.M.F. = 1·257IT, where I is the current in amperes and T is the number of turns. The symbol for the words ampere-turns is Ā. (Ā = IT).

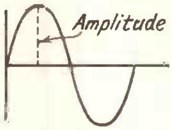
Amplification.—Magnifying, increasing the amplitude of electrical variations in the intensity of electrical power, an E.M.F. or current.

Amplification Factor.—A term used in conjunction with a thermionic valve. It is the product of mutual conductance and the anode impedance.

It is also used in connection with an amplifying device as a whole, and then it is the ratio of power, E.M.F., or current, at the output end, and the power, E.M.F., or current, at the input end.

Amplifier.—A complete unit performing amplification. Thus in wireless reception we can have a high-frequency amplifier consisting of a number of H.F. valves and their respective components, or a low-frequency amplifier made up of L.F. valves and their accessories.

Amplifier, Cascade.—An amplifier in which the valves are connected in series (in the usual way as distinguished from parallel connection of valves as push-pull rectification or amplification



Amplitude.—The maximum instantaneous value of E.M.F. or current during the half-cycle.

Angle of Lag.—The interval of time by which a current is retarded by the self-inductance of the circuit (a property akin to mechanical inertia) after an E.M.F. comes into action.

Angle of Lead.—The interval of time by which a condenser discharge current, or any current in a capacitative circuit, leads the charging E.M.F. In other words, the discharge current happens *before the next quarter of the cycle* o the applied E.M.F. takes place.

Anode.—The positive electrode. The electrode which is made poor in electrons, and therefore has a predominance of protons.

Anode Battery.—Another name for *high-tension battery.*

Anode, Battery.—The positive plate of a battery.

Anode Bend Rectification.—A method of detection of wireless signals. The working value of current flowing through the valve is so chosen, by adjusting the anode voltage, the grid voltage and the filament current, that it is on either the lower or the upper bend of the valve characteristic curve. If the point chosen is on the lower bend then there is, for a given positive-negative change in grid voltage, a larger increase than decrease in anode current. With the upper bend, for a given positive-negative change in grid voltage, there is a smaller increase than decrease in anode current.

Anode Circuit.—The circuit comprised by components connected between the anode of a valve and the positive terminal of the high-tension battery. This circuit includes the H.T. battery and the lead connecting it to the L.T. battery.

Anode Converter.—A rotary electrical machine for supplying anode voltage. There are two types of such machines in existence. One is for supplying D.C., and consists of two windings mounted on the same shaft, of which one is a D.C. motor winding run from accumulators and the other a D.C. or dynamo winding supplying direct current. This machine has two commutators. The other type consists of a motor winding as before, while the second winding is an alternator winding supplying an alternating current. This machine has a commutator at the motor end and slip rings at the other end. The first type of machine is called a *motor-generator set*, and the second type a *rotary converter*, the word converter indicating the conversion of a D.C. input into the motor into an A.C. output by the alternator winding. What happens is that the current supplied by the accumulators to the motor causes the latter to rotate and drive round the dynamo or the alternator winding. Such machines are built commercially for use with wireless receivers, and, being silent in their operation, are suitable for home use.

Anode Current.—The current flowing in the anode circuit of a valve.

Anode Dissipation.—When a current is flowing through a valve the anode becomes heated, owing to the bombardment of electrons from the filament. Thus electrical power becomes dissipated in the form of heat at the anode. The power thus dissipated in watts is given by the product of anode volts and anode current.

Anode Resistance.—Name of a component connected in the anode circuit which has an ohmic resistance of the order of thousands of ohms. This is usually a non-inductive resistance.

Anode, Valve.—A valve electrode, usually in the form of a flat metal cylinder, which surrounds the grids and the filament. It is kept in position by a rigid support, and is connected to the outside circuit through one of the valve legs or a separate terminal. It is also referred to sometimes as the *plate.*

Antenna.—A Continental term for an elevated aerial.

Anti-Capacity Switch.—A switch in which the contacts are so spaced as to offer as little capacity as possible. This is important in the case of short waves, *i.e.*, very high-frequency circuits.

Anti-Microphonic Valve.—When a valve is mounted within a set near a loud speaker the mechanical vibrations due to sound waves cause the valve to vibrate and may force its electrodes to change their relative position. This means a change in inter-electrode capacity, which affects the quality of signals. Valves designed extra rigidly and placed into shock-absorbing valve holders are used to counteract this tendency. Thus all extraneous or microphonic noises are eliminated to a very great extent.

Aperiodic.—A circuit that cannot be tuned to any particular frequency. An untuned circuit.

Aperiodic Aerial.—An aerial which has no means of tuning to any particular wavelength. It is inductively coupled to a tuned secondary circuit. Since every aerial by virtue of its length of wire and height has a natural wavelength of its own, there is no aerial truly aperiodic, and it will respond best to some wavelength equal to its natural wavelength.

Apparent Inductance of a Coil.—An oscillatory circuit made up of a coil and a condenser in parallel will respond best to a current of a frequency, the corresponding wavelength of which is directly proportional to the product of the coil inductance and the capacity of the condenser. In practice, however, the capacity of the circuit is somewhat higher than the capacity of the condenser, as the coil also has capacity between its turns, and this capacity in parallel with the condenser capacity gives a resultant larger capacity. For this reason the measured wavelength is slightly higher than the calculated wavelength. The circuit behaves as if there were a larger inductance coil (and no self-capacity) in parallel with the condenser, and this is the *apparent inductance of the coil.*

Apparent Power.—In a direct-current circuit the power developed in the circuit is the product of voltage and current. In an alternating-current circuit the product of root mean square values of voltage and current will give not the true but the apparent power. The true power developed in such a circuit is equal to the product of r.m.s. values of voltage and current multiplied by the *power factor.*

Apparent Resistance.—In an alternating-current circuit, if we divide the voltage by the current we shall obtain an apparent resistance which is the impedance of the circuit, and not its true ohmic resistance. The latter can be ascertained by applying to the circuit a direct E.M.F. and finding the current flowing. Then the voltage divided by the current will give the true resistance of the circuit.

Appleton Layer.—About 142 miles above the surface of the earth there is supposed to be a second ionised layer (the first is the Kennelly-Heaviside layer), which is responsible for reflecting short waves to earth. These short waves pass the Kennelly-Heaviside layer without reflection, and are merely somewhat weakened by it.

Applied E.M.F.—An E.M.F. impressed upon a circuit with the help of some source of an E.M.F., such as a battery, a dynamo or an alternator. The term applied is used in order to distinguish the applied E.M.F. from an induced E.M.F.

Armature.—A system of conductors placed in slots of a laminated iron drum which is made to rotate in a magnetic field. The conductors thus have an E.M.F. induced in them. The connections to the external circuit are made *viâ* a commutator in the case of a dynamo, and slip rings in the case of an alternator.

Artificial Aerial.—A radiating aerial has a definite resistance, inductance and capacity. It is possible to arrange an equivalent electrical circuit which will have the same resistance, inductance and capacity as a given type of a radiating aerial. This circuit will, naturally, not radiate, and for this reason it is called an artificial aerial. Such a circuit is used for experiment by "wireless" amateurs who do not possess a transmitting licence, but have one for the use of an artificial aerial.

Artificial Line.—An electrical circuit possessing the resistance, inductance and capacity of a given telephone line, and thus representing an artificial line equivalent to the real line of given dimensions.

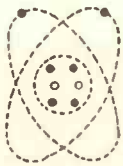
Astatic Coil.—The magnetic field around a coil carrying a current depends for its direction upon the sense in which the coil turns are wound. It is possible to arrange this winding in such a way, by changing its sense, that the directions of magnetic fields will oppose each other, and thus cancel each other out. An astatic coil may therefore have no or very little magnetic field around it.

A.T.C.—Aerial tuning condenser.

A.T.I.—Aerial tuning inductance.

Atmospherics.—These are also called X's, strays or static. Atmospherics are electro-magnetic waves produced in the ether by some atmospheric electrical discharge, such as a discharge between two clouds or from a cloud to earth. Such waves, naturally, affect wireless reception, and there is no effective method at the moment of getting rid of them. Atmospherics are more active in the summer than during the winter.

Atom.—An atom can be represented as a miniature solar system. It consists of a nucleus and a number of "planetary" electrons rotating around the nucleus, just as planets rotate around the sun. The nucleus is made up of two particles of electricity, electrons (negative electricity) and protons (positive electricity). The electrons within the nucleus are called "cementing" electrons. In every atom there are as many electrons as there are protons. All the protons are concentrated in the nucleus. The electrons are partly within the nucleus and



partly outside. An atom of one chemical element differs from an atom of another chemical element by the number of electrons and protons in it. The atomic weight is equal to the number of protons in the nucleus, *i.e.*, in the atom. The atomic number is equal to the number of planetary electrons in the atom. The difference between the atomic weight and the atomic number indicates the number of cementing electrons within the nucleus. The weight of an atom of hydrogen is taken as unity (it consists of one proton and one electron) and all other atomic weights are multiples of it. Atomic numbers are merely serial numbers of atoms arranged in the ascending order of atomic weights. Since the atom of each chemical element has a different number of electrons and protons, the size of atoms differs considerably. An atom of the gas helium, for instance, has a diameter of 1/400,000,000 of an inch.

When an atom has its normal, and therefore equal, number of electrons and protons, it is electrically neutral. The forces between electrons and protons are perfectly balanced. (Electrons repel each other, so do protons; but an electron will attract a proton.) Should an atom lose some of its planetary electrons it becomes positively charged, as there is now a predominance of protons. Should it gain some electrons from outside, it becomes negatively charged, as there is now a predominance of electrons.

Attenuation.—Weakening of wireless waves with distance. Decrease in the amplitude of E.M.F., current or electro-magnetic wave.

Attenuator.—A type of resistance control providing pre-determined attenuation.

Audibility.—A human ear cannot hear all kinds of sounds. It will hear sounds produced by air vibrations having a frequency ranging approximately between 30 and 10,000 vibrations per second (this varies with the individual). These two frequencies are the approximate limits of audibility.

Audio-Frequency.—A frequency of alternating current which can produce audible sounds with the help of telephones or loud speaker. The audio-frequencies lie within the limits of 30 and 10,000 cycles per second. These frequencies are also referred to as low frequencies.

Audio - Frequency Amplification. — Low - frequency amplification, *i.e.*, amplification after the detector stage.

Audio-Frequency Transformer.—Low-frequency, iron-cored, step-up transformer used in the after detector stages.

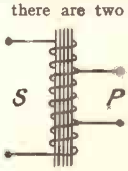
Audion.—American name for an early type of a three-electrode valve.

Autodyne.—An electrical oscillating circuit in which the anode and the grid of the valve are connected to a common coil, forming an auto-transformer (which see). This circuit is mainly used for transmission purposes.

Auto-Heterodyne (also referred to as Endodyne).—A method of beat reception in which the E.M.F., induced by a wave of the received frequency, is combined with an E.M.F. of another frequency, produced locally with the help of an oscillating valve incorporated in the receiver. The detector and the amplifier deal with the combination of the two frequencies.

Automatic Grid Bias.—A method of giving the grid of a valve a bias through a resistance. It is arranged in such a way that one end of the resistance is in electrical connection with the grid. When a varying current is flowing through such a resistance there is a varying difference of potential (voltage drop) across it, so that while the current varies the potential applied to the grid is varied automatically.

Auto-Transformer.—In an ordinary type of transformer there are two windings. An auto-transformer has only



one which is used for both the primary and the secondary. In a step-up transformer of this type the primary winding is represented by a tapped portion of the coil, say, a number of the centre turns. When an alternating E.M.F is applied to such a primary, an alternating current flows in it. This current produces an alternating magnetic field which links with the turns of the *whole coil,* and not only with the tapped portion of it. For this reason there is an alternating E.M.F. induced across the coil as a whole; in other words, across the secondary of the auto-transformer. In this manner the transformer action is obtained, as the secondary "winding" has many more turns than the primary tapped portion. Within certain limits auto-transformers are more economical to build than ordinary transformers, as there is a considerable saving in copper, but this only applies to small transformers.

B

"B" Battery.—An American name for the high-tension battery.

Back E.M.F.—When an alternating E.M.F. is applied to a coil, if this coil is part of a closed circuit an alternating current will flow in the circuit and will produce an alternating magnetic field around the coil. This alternating magnetic field will move in space, and its lines of force will cut the turns of the coil, inducing in them an E.M.F. additional to the applied E.M.F. This induced, or rather, self-induced E.M.F. will oppose at every instant the applied E.M.F., and, for this reason, it is called the back E.M.F.

Back Lash (also referred to as Overlap).—In a receiver employing reaction, if the valves are given wrong anode or/and grid voltages or components of unsuitable values are used, an increase in reaction may cause a howl to start long before the coupling between the reaction and the aerial coils is made such as to cause oscillations. The reaction coil has to be taken back for the howl to cease. This amount of retrograde movement is called the backlash. The remedy for this state of affairs is obvious.

Baffle.—A rigid, non-resonating board with a circular opening in the centre, to which the edges of the cone diaphragm of the loud speaker are attached. In the ordinary way, without a baffle, a loud speaker in vibrating will send out air waves to the back and front, thus dissipating its energy and causing the low notes (bass) to disappear. The use of the baffle remedies this defect. For good bass response the baffle should be made of hardwood, $\frac{7}{8}$ inch thick, 5 feet in diameter, and should be rigidly built in. An alternative is to use a baffle in the form of a box, which can be much smaller, and, in order to avoid booming, the walls of the box are thickly lined with slag wool.

Balanced Armature.—The armature in question is that of a moving iron loud speaker, a relay or a pick-up. Such an armature represents an iron bar, pivoted in the centre between symmetrically placed magnet poles. It moves symmetrically about this centre in that while one end is being attracted the other end is being repelled. In the case of the loud speaker the armature is mechanically connected to a cone diaphragm, which it causes to vibrate while vibrating itself.

Balancing Aerial.—In duplex (two-way) telephony an aerial placed at right angles to the receiving aerial. These two aerials are so designed that reception and transmission of signals can be carried out at the same time.

Balancing Capacity (also referred to as Counterpoise or Capacity Earth).—A system of insulated wires placed under the aerial as an alternative to earth connection. In this case it is the aerial and the balancing wire that form the two plates of a condenser between which the arriving electric field of the incoming electro-magnetic wave establishes itself. This method of reception can be used in flats where an earth connection is impossible. In such a case the aerial wire is erected in a zig-zag fashion under the ceiling, and the earth connection is replaced by a similar zig-zag system of insulated wires under the carpet. The counterpoise is then treated as an "earth."

Ballast Tube.—An American name for barretter.

Band-Pass Filter.—A tuning filter circuit which will offer a low resistance to currents induced by waves of predetermined frequencies, rejecting all others.

Band-Pass Tuning.—A tuning system using a number of oscillatory circuits loosely coupled either inductively or by means of condensers, or both, used in receiving circuits. Such a system is claimed to avoid losses causing bad quality of reproduction in ordinary receivers.

B. & S. Gauge.—The Brown and Sharpe (American) wire gauges.

Banked Winding.—An old-fashioned method of winding tuning coils. The banking consists of crossing the first layer and starting the winding on the side opposite to that on which the first layer was started. This method of winding reduces the self-capacity of the coil.

Barretter.—A device for maintaining a current in a circuit at constant strength in spite of any variations of voltage, within certain limits, across the circuit. One form of it is a small glass tube filled with hydrogen through which passes a fine wire made of an alloy, the resistance of which rapidly increases with the increase of temperature, *i.e.*, with the increase of current strength. Thus, when the voltage has a tendency to increase, a larger current comes into existence, but the wire's resistance promptly increases with the increase of current, so that the current is once more reduced to its previous value in spite of the increase of voltage.

Basket Coil.—A flat coil wound in such a way that its turns are superimposed and interlaced so as to give an appearance of the bottom of a basket. The winding is done with the help of a flat, round former carrying a number of radial pegs. The wire is carried over and under each peg alternately.

Battery.—A name given to a number of primary or secondary cells connected together.

Battery, Dry.—This is a collection of primary cells of small size, which have moist chemicals instead of liquid ones, as in the case of ordinary primary cells. The cells, apart from a vent hole, are hermetically sealed so that there can be no leakage. Hence the name dry.

Battery Eliminator.—An electrical circuit which "eliminates batteries," *i.e.*, serves as an alternative to them and provides a suitable voltage for valves direct from the mains. There are two types of battery eliminators—one for A.C. mains and one for D.C. mains. The eliminator for A.C. mains contains some sort of rectifier which converts alternating current into direct current, together with some smoothing devices consisting of chokes and condensers. A transformer is used before the rectifier for dropping the mains voltage. In the case of a D.C. supply, the voltage is dropped with the help of resistances, and smoothing devices are used to even up any irregularities in the supply voltage. The D.C. battery eliminator is more difficult to design satisfactorily than the A.C. one.

Battery, Inert.—A type of dry battery specially designed for hot climates. It is made in such a way that it remains inactive without damage for long periods till water is added to it. Thus it cannot deteriorate while in transit or in stock.

Beam Transmission.—A directional method of short-wave transmission in which a special reflector system of wires is used in addition to the transmitting aerial, so that the radiated waves leave the aerial in the form of a divergent beam having an angle of some 10 to 15 degrees instead of being radiated in every direction. This method is more economical than the usual method as a greater amount of energy can be directed in a given direction with much less power being expended. It also ensures a certain amount of secrecy. This system is due to Marconi.

Beat Frequency.—The numerical difference in the frequencies of two interfering waves, *i.e.*, the frequency of the resultant or "beat" wave.

Beat Reception.—A method of reception of wireless signals in which the received oscillations are combined with oscillations produced locally in the receiver. The two sets of oscillations combine, producing a resultant or "beat" oscillation of its own frequency equal to the difference between the frequencies of the combined individual oscillations. The result is thus far removed in frequency from the received frequency, and therefore from close-lying interfering frequencies. This principle is used in superheterodyne receivers.

Beats.—If two tuning forks having close-lying frequencies of vibration are excited simultaneously, the note heard is not that of either of the tuning forks, but a new note which has a frequency equal to the difference in frequency of the two tuning forks. In this manner a frequency of 1,000 cycles per second and a frequency of 800 cycles per second will produce a resultant or beat frequency of 1,000–800 or 200 cycles per second. The combination of two notes into one is called the *beat* of two notes. Electrical oscillations of different frequencies behave in a similar manner.

Bel.—A unit of loss or gain in power used in transmission. One bel is the logarithm to the base ten of the ratio of two powers which are being compared.

Bellini-Tosi System.—A system of two aerials placed at right angles and connected to two coils fixed in position, also at right angles, within which a third coil is rotating. The strength of signals received from various directions is judged with the help of an ordinary detecting circuit and telephones and the direction of incoming signals thus ascertained. Modern direction finders use two frame aerials at right angles (Dr. Robinson's system).

Beverage Aerial.—A directional aerial of low height which has a length equal to some multiple of the wavelength which it is desired to receive. Used for work in connection with atmospherics.

B/H Curve.—The symbol B is used to denote magnetic flux density in a magnetic material. The symbol H denotes the magnetising force or the flux density in air. The B/H curve is therefore a graph showing the relation between magnetic flux density in a magnetic material and the flux density in air. This curve is also referred to as the magnetisation curve. Since the permeability of air is taken as unity, the ratio B/H denotes the permeability of the material under magnetisation.

Bias.—This word means in the ordinary way inclination, predisposition, prejudice, influence. In the electrical sense it means a conductor being given an initial potential, which thus forms the basis of future variations of potential (see Grid Bias).

Bias Resistance.—A resistance used in automatic grid bias (which see).

Binding Post.—An American name for a terminal.

Blasting.—A term used to indicate electrical distortion in a loud speaker due to valve overloading.

Blattnerphone.—An instrument for recording speech and music on a steel tape passing at some predetermined speed under an electro-magnet connected to the microphone amplifier circuit. The variable magnetic field controlled by modulated currents is permanently recorded on the steel tape which, when run afterwards near a coil connected to an amplifying reproducing system, will cause the recorded signals to be reproduced by induction. This system is used extensively by the B.B.C. for recording important broadcasts, and also for re-broadcasting for the Empire short-wave service.

Blind Spots.—Localities within the service area of a station where for some reason, such as screening, signals can be received only very faintly.

Blocking Condenser.—A condenser having a fixed capacity used for stopping a flow of direct current in an undesired direction. Also used for altering the capacity of a circuit.

Bobbin.—A coil of insulated wire wound on some suitable former ready for mounting on an iron core, or to be fixed to a baseboard.

Bornite.—A natural sulphide of iron and copper (Cu_5FeS_4). Its crystals are of cubic form and have an iridescent blue and red colour. Used as a detector of wireless signals.

B.O.T. Unit.—This is an abbreviation for the Board of Trade unit of electrical power and represents 1 kilowatt-hour (1 kilowatt is 1,000 watts).

Box Baffle.—A baffle in the form of a box for use with cone loud speaker. Resonance or "booming" is counteracted by lining the interior walls with slag wool.

Bridge.—A name given to a special balancing arrangement of electrical components resistances, coils or condensers for the purpose of measurement of unknown electrical quantities (see Wheatstone Bridge).

Bright Emitter.—A name used for the old-fashioned valves used in wireless reception, the filament of which emitted light.

Brush Discharge.—A luminous escape of electrons from sharp points raised to a very high potential. This frequently occurs on conductors forming parts of high-power circuits.

B.Th.U.—An abbreviation which stands for the British thermal unit. One British thermal unit is the quantity of heat necessary to raise the temperature of 1 lb. of water 1° Fahrenheit. One B.Th.U. is equivalent to 778 foot-pounds of mechanical work.

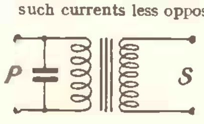
Bulb.—A glass container of valve electrodes, an electric lamp filament, a fuse, etc.

'Bus Bar.—Abbreviated omnibus bar. An omnibus bar is a common conductor used for connecting a source of an E.M.F. to a number of various circuits. This term is used mainly in connection with power station work.

Buzzer.—An instrument reminiscent of the electric bell mechanism, but without the gong, the vibrating armature of which is made to produce a buzzing sound.

Buzzer Wavemeter.—A form of a wavemeter using a buzzer for the purpose of production of oscillations. Used for calibrating the tuning circuits of wireless receivers.

By-Pass Condenser (also known as the Bridging Condenser).—This is a fixed capacity condenser connected across a component in which the flow of high-frequency currents is undesirable. The by-pass condenser offers to such currents less opposition than the component in question, which usually possesses a considerable amount of self-inductance. Thus a by-pass condenser may be connected across the primary of an L.F. transformer, across a choke, or across a loud speaker. A 2-mfd. condenser is usually connected across a H.T. battery in order to smooth out any irregularities that may be present in this source of supply owing to deterioration of one or more cells.



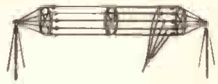
C

"C" Battery.—An American term for grid-bias battery.

Cable.—Cables used in electrical engineering consist of a number of stranded conductors twisted in groups and heavily insulated and sometimes armoured. They are used either for transmission of electrical power, as in land underground systems, or for connecting continents, as submarine cables for the purpose of telegraphy and telephony.

Calorie.—This is a unit of heat. One calorie represents a quantity of heat which will raise the temperature of 1 gramme of water 1° Centigrade. One British thermal unit is equivalent to 252 calories.

Cage Aerial.—In order to reduce the resistance of an aerial to the flow of high-frequency currents a number of conductors is connected in parallel, the aerial thus acquiring the appearance of a cage. The aerial wires are fixed to a circular pair of spreaders.



Capacitance.—An American term for capacity.

Capacity.—Every atom has a definite natural number of "planetary" electrons. It is only these electrons that can pass from atom to atom and thus give rise to electrical phenomena. An atom can lose or gain only a limited number of electrons, *i.e.*, an atom has a limited *capacity* for both gain and loss of electrons. A metallic conductor when charged either negatively (a surplus of electrons) or positively (a deficit of electrons, *i.e*, a predominance of protons) has either a surplus or a deficit of electrons in its surface atoms (in electro-static phenomena it is only the surface atoms that come into play).

Since the number of surface atoms is definite and depends upon the surface area of the conductor, the conductor, as a whole, has a definite capacity for losing or gaining electrons.

Capacity Bridge.—Wheatstone bridge when used for balancing capacities in order to find an unknown capacity.

Capacity, Condenser.—The capacity of a condenser, be it of fixed type or variable, depends upon three things: 1, the plate area—the larger the plates the larger the capacity of condenser; 2, the distance between the plates (which is the same between each pair of plates)—the smaller this distance the greater the capacity; and 3, the dielectric constant of the insulating medium between the plates. The capacity of a fixed, parallel plate condenser is found from:

$$C = 0{\cdot}0885 \times k \times \frac{A\,(n-1)}{d} \text{ micro-microfarads, where}$$

k is the dielectric constant, found from tables.

A is the area of one of the plates, in square centimetres.

n is the number of plates ($n - 1$ equals the number of layers of dielectric There is no capacity between the top surface of the top plate and the bottom surface of the bottom plate, hence we have the number of plates less one entering into our formula).

d is the distance between a pair of plates in centimetres.

The capacity of a fixed condenser consisting of two co-axial cylinders is found from:

$$C = 1{\cdot}112\,\frac{k\,L}{2\log_e \frac{r_1}{r_2}} \text{ micro-microfarads, where}$$

L is the length of one of the cylinders which are equal in length, in centimetres.

r_1 is the radius of the larger cylinder in centimetres.

r_2 is the radius of the smaller cylinder in centimetres.

$\log_e$ of the resultant number is found from the tables of natural logarithms.

The capacity of a variable, parallel plate, condenser is found from:

$$C = 0{\cdot}139 \times k \times \frac{(n-1)\,(r_1^2 - r_2^2)}{d} \text{ micro-microfarads,}$$

where k, n and d are as before.

r_1 is the radius in centimetres of one of the moving plates.

r_2 is the smaller radius in centimetres (of the cut-out semicircle) of the fixed plate.

Capacity Coupling.—Inserting a condenser between two circuits.

Capacity Earth.—The same as Balancing Capacity.

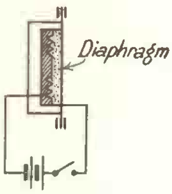
Capacity Reactance.—In an alternating current circuit the opposition to the flow of alternating current is made up of three oppositions: 1, the ordinary ohmic resistance as met in direct current circuits; 2, opposition due to the self-inductance of the circuit which retards the growth or the decay of current, and is known as the *inductive reactance*; and 3, opposition due to the repulsive forces exercised by the electrons in the surface atoms of condenser plates during charging and the attractive forces of the protons in the surface atoms during discharging. It is clear that this opposition depends upon the capacity of the condenser and is less the greater the capacity, as with a greater capacity more electrons can be accepted or more electrons released. For this reason capacity reactance is expressed $\frac{1}{2\pi f C}$. The reason why the frequency comes into the formula is that the more often the current changes its direction, and therefore the more often the condenser becomes charged and discharged each second, the more opposition there is in each second. π is a constant number equal to 3·1416.

Capacity Reaction.—A method of obtaining reaction by connecting the anode of the detector valve to the grid circuit of the first H.F. valve. An alternative to ordinary inductive reaction coupling.

Capacity, Specific Inductive.—The specific inductive capacity of a dielectric is the ratio of the condenser capacity with this dielectric to the capacity of a condenser with air as dielectric. It is also called the *dielectric constant* or *permittivity*.

Carbon.—A chemical element which exists in its pure state in the form of a diamond. Another form of carbon is graphite. It is also present in antnracite.

Carbon Microphone.—A form of a microphone which can vary the resistance of an electrical circuit under the influence of a vibrating carbon diaphragm. It consists of a carbon grooved block filled with carbon granules (graphite variety) upon which presses the carbon diaphragm. The microphone is so connected in circuit that the current passes from the carbon block *viâ* the granules to the diaphragm. With a varying pressure of the diaphragm the compression of the carbon granules varies, and, therefore, their resistance to the passage of the current varies.



Carrier Current.—In a telephone circuit when you pick up the receiver you automatically connect the battery in circuit and cause a current to flow. You hear nothing, however, till the microphone diaphragm starts to vibrate at the other end and the microphone starts to vary the resistance of the circuit which causes the current that is flowing to vary. Thus the original steady current is the basis of the variations caused by vibrations of the microphone diaphragm. It *carries* these variations, and for this reason it is called the *carrier current.*

In the case of wireless the carrier current is represented by the uniform high-frequency current flowing in the aerial before the currents from the microphonic circuits are superimposed upon it. Thus, again it carries the microphonic variations and is the carrier current.

Carrier Frequency.—The frequency of the carrier current flowing in the aerial (see Carrier Current).

Carrier Wave.—The wave radiated by the carrier current flowing in the aerial. This carrier wave, naturally, does not bear any speech or music characteristics, and may be picked up sometimes as a high-pitched note.

Cascade.—A term indicating the manner of connecting wireless components, in which the output of one component is connected to the input of the next, and so on. The usual way of connecting valves.

Cathode.—The negative side or terminal of battery or cell. The negative electrode of a valve or photo-electric cell. This is the electrode rich in electrons which serves as the starting-point of electron migration through a circuit or as a source of electron emission through the inter-electrode space.

Cathode Ray Oscillograph.—This is a highly exhausted glass tube of a special design in which with a high applied voltage an electron stream is made to proceed from the cathode and fall upon a fluorescent (luminous) screen. By applying varying magnetic fields it is possible to make the end of the electron stream move across the screen in two directions, and thus, with a varying electric current causing the magnetic fields in question, produce a visible luminous track of the motion of the stream. In this manner the wave form of alternating currents is made apparent in a visible manner.

Cat's Whisker.—A metal wire in contact with a crystal in wireless reception. The reason for its use is that not all points on the surface of a crystal used in wireless reception are equally sensitive, and therefore a point contact is essential.

Cell.—A term applied in electrical engineering to an arrangement of two or more electrodes or plates in an electrolyte, as in the case of primary and secondary cells, or to the two electrodes in vacuum, as in the photo-electric cell, or to an arrangement between two plates of some material which varies its resistance under the influence of a variable illumination, as in the selenium cell.

Cell, Photo-electric.—A glass bulb, carrying two electrodes, which varies the current flowing through it with the variation of intensity of light falling upon it. Used mainly in television. The photo-electric cell offers the means of interpreting light variations in terms of a varying electric current.

Cell, Primary.—A class of cells to which belong the Daniel, Leclanché and the Weston cells. Such cells do not need to be charged by passing an electric current through them. A depolarising agent is used to prevent polarisation (which see).

Cell, Secondary.—(See Accumulator.)

Cell, Selenium.—Selenium, which is a chemical element, has a peculiar property of varying its resistance with the intensity of illumination. Thus in the dark the resistance of selenium is very large, and, as more and more light is made to fall upon it, its resistance diminishes. Thus it will act as a sort of a photo-electric cell when connected in circuit. Selenium cells are made for this purpose, and are used chiefly for burglar alarms, railway automatic signalling, automatic street lighting, etc.

Centimetre.—The French unit of length used in the C.G.S. system. Electrically, a capacity of 1 centimetre is equivalent to 1/900,000 microfarad.

C.G.S. Units.—A system of units in which the unit of length is the centimetre, the unit of mass is the gramme and the unit of time is the second. The words centimetre, gramme, second, give the initials C.G.S.

Characteristic Curve.—A graph showing the relation between two quantities when one is varied and other dependent quantities being kept fixed. Thus we have valve characteristic curves (static) which may show the relation between anode current and grid volts, the anode voltage and the filament current remaining constant. We may also have a graph showing the relation between anode volts and anode current with a given grid potential and filament current. A similar graph will show the variation of current with a varying voltage in the case of a crystal.

Charge.—An electric charge is either a surplus or a deficit of electrons in the surface atoms of a metallic conductor or an insulating substance. In the case of metals the charge is uniformly distributed over the surface of the body, *i.e.*, every surface atom has the same surplus or the same deficit. In the case of insulators the charge is confined to a localised area on the surface to which it is directly applied by the charging source. A negative charge means a surplus of electrons and a positive charge means a deficit of electrons, *i.e.*, a predominance of protons.

Check Receiver.—A wireless receiver used inside a broadcasting station to verify the quality of transmission.

Chemical Effect of Electrical Currents.—This manifests itself in that when a current flows through a saline solution it decomposes this solution into its constituent parts. The function of accumulators and the electrolysis rest upon this effect. The international definition of the *ampere* (which see) is based upon the chemical effect.

Choke.—A coil of wire which has a large inductive reactance as compared with its resistance. This means a large self-inductance which develops a considerable back E.M.F. There are two kinds of chokes: 1, the high-frequency choke (abbreviated H.F.C.), which is wound upon an insulating former and has no iron core. This is also known as an *air-core choke.* Its function is to offer a large opposition to high-frequency currents with a view of developing a large back E.M.F. across the coil for amplification purposes: 2, the low-frequency choke, which is a coil wound upon an iron core and which offers a large opposition to high-frequency currents while offering little opposition to low-frequency currents. Its function is to by-pass high-frequency currents on account of its self-capacity, and to produce a low-frequency back E.M.F. across the coil for amplification purposes. The word choke implies that it "chokes" the current on account of its high self-inductance.

Choke Capacity Coupling.—A method of intervalve coupling. The choke is connected in the anode circuit of the valve, being placed between the anode of the valve and the positive terminal of the H.T. battery or supply. Another connection is taken from the anode of the same valve through a condenser to the grid of the next valve. Hence the name choke capacity coupling.

Choke Capacity Filter.—An output circuit consisting of a low-frequency (iron-cored) choke connected between the anode of the output valve and the loud speaker circuit. The latter consists of the loud speaker winding with a condenser across it.

Choke Control.—A method used in transmission to vary the amplitude of high-frequency oscillations for modulation purposes.

Choke, High-Frequency.—(See Choke.)

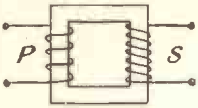
Choke, Low-Frequency.—(See Choke.)

Circuit Breaker.—An automatic switch which breaks an electrical circuit when the latter is overloaded, and thus prevents damage of measuring instruments, etc., in the circuit.

Cleats.—Insulated U-shaped pieces of metal for fixing wiring to the wall.

Close Coupling.—Also referred to as tight coupling. Two coils are closely or tightly coupled when they are brought close to each other, so that each coil is within the maximum magnetic field of the other coil and the maximum mutual induction is taking place.

Closed Core Transformer.—A transformer possessing an iron core which is closed upon itself, thus forming a closed magnetic circuit without an air gap being present. There are several forms of such closed cores



Coefficient.—A term used in algebra indicating a constant number placed before a letter or a combination of letters which denote certain values. In engineering it is used to denote a ratio (fraction) of two quantities or a degree of some electrical action.

Coefficient of Amplification.—Also referred to as amplification constant or amplification factor (which see).

Coefficient of Coupling.—This is the ratio $\frac{M}{\sqrt{L_1 L_2}}$ where M is the mutual inductance between two coils and L_1 is the inductance of one coil, while L_2 is the inductance of the other coil.

Coefficient of Mutual Induction.—Another name for mutual inductance (which see).

Coefficient of Self-induction.—Another name for self-inductance or simply inductance. It denotes the degree of self-induction of a coil.

Coercive Force.—When a piece of iron is magnetised and then demagnetised, it is found that on demagnetisation it does not altogether lose all its magnetism. In order to get rid of the residual magnetism a reversed magnetic field is applied to the iron so as to *coerce* it to lose its remaining magnetism. The force exercised by this reversed field is called the coercive force.

Coherer.—An early piece of apparatus for detecting Morse signals sent by wireless. This consists of a glass tube filled with metallic filings which cohered together when a high-frequency electrical impulse passed through the filings. The coherer had to be tapped to loosen the filings after the passage of the impulse, and this was done automatically. Hence the coherer is an early form of a wireless detector.

Commutator.—A circular cylinder mounted on the end of the shaft of a dynamo or a D.C. motor made up of copper segments separated by segments of insulating material. The copper segments are connected to the armature conductors. Carbon brushes resting upon the commutator make contact with the outside circuit.

Condenser.—An electrical condenser consists of a pair or a number of plates of metal separated by dielectric (insulating substance). There are two main types of condensers—*fixed* (capacity) and *variable* (capacity). In fixed condensers the plates and the intervening layers of dielectric are rigidly fixed under pressure and the whole enclosed in an insulating container, with two terminals, one terminal for each set of plates. Variable condensers consist of two sets of vanes, of which one set is rigidly fixed and the other set can be rotated, varying the overlapping area between the fixed and the moving vanes. It is this variation in the overlap area that varies the capacity of a condenser in a continuous manner. In the case of fixed condensers the dielectrics used are mica or paraffined paper (for larger capacities of the order of 2 mfds.). In the case of variable condensers the dielectric is, as a rule, air. A condenser will not let *through* any kind of current, be it direct or alternating (a current cannot pass through the dielectric). People talk about a condenser letting through alternating currents. What they mean is that an alternating current charges the condenser and the condenser discharges itself during part of the cycle. All that happens is that electronic tides take place in the circuits on both sides of the condenser.

Condenser Loud Speaker.—Also referred to as electro-static loud speaker. When two electrified metal plates are placed close together there is either repulsion or attraction between them on account of similar and dissimilar charges respectively. If one plate is rigidly fixed and the other is flimsy enough to vibrate freely, as the charges vary so the diaphragm will vibrate and disturb the air, producing sound waves. This is the principle upon which the electro-static loud speaker works.

Condenser Microphone.—The capacity between two plates depends upon the distance between the plates (amongst other things). Thus, if we have a metallic diaphragm vibrating close to a metal plate, the whole forming a condenser, the capacity of the combination will vary, and if this is connected to an electrical circuit, the current in the circuit will vary with the variation of capacity. This is the principle of construction of the condenser microphone used in broadcasting.

Conductance.—This is the opposite to resistance. The greater the resistance of the circuit the worse it conducts the current, and therefore the smaller is its conductance. Mathematically the relation between the two is shown as Conductance $= \frac{1}{\text{Resistance}}$. If the resistance of a circuit is 10 ohms, then the conductance is $\frac{1}{10}$ or 0·1 mho. Conductance is measured in units called mho, which is the word ohm reversed. Thus one mho $= \frac{1}{\text{one ohm}}$.

If resistance, in direct circuits, in accordance with the Ohm's law is $R = \frac{E}{I}$ and conductance is $\frac{1}{R}$, then conductance $= \frac{I}{E}$, or is the ratio of current to the E.M.F.

Conductive Coupling.—This is a method of coupling two circuits through a conducting path.

Conductivity.—The reverse of resistivity. Conductivity $= \frac{1}{\text{resistivity}}$. Since resistivity is measured in ohms, conductivity, like conductance, is measured in mhos.

Conductor.—A substance allowing a free interchange of electrons between atoms when an E.M.F. is applied across the substance. The best conductors are water, metals and some of their alloys.

Contact Breaker.—An automatic device for opening and closing a circuit.

Continuous Current.—Abbreviated C.C. This is also referred to as direct current (D.C.), a current flowing continuously at constant strength under the influence of a steady E.M.F.

Continuous Oscillations.—These are continuous, *i.e.*, uninterrupted oscillations of electrical currents produced either by an alternator or a valve, and the carrier current in the transmitting aerial is of this character.

Continuous Waves.—Electro-magnetic waves inducing continuous oscillations of electrical currents, or alternately radiated by an aerial carrying continuously oscillating currents.

Control Grid.—The input electrode of the thermionic valve, placed between the filament and the anode in a three-electrode valve and between the filament and other grids in the case of a multi-electrode valve.

Control Room.—The part of a broadcasting station from which all electrical circuits are controlled and where connections are made between the various studios and transmitters.

Control System.—The portion of the transmitting circuit in which high-frequency oscillations are modulated.

Convertor.—A piece of apparatus which converts one form of electrical energy into another (see Anode Convertor).

Copper Loss.—Loss of electrical energy wasted in the form of heat, etc., in the copper conductors of an electrical machine.

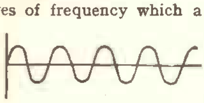
Corona.—This is a phenomenon which may have either a natural origin in the form of Corona Borealis (northern lights), which is assumed to be an atmospheric series of electrical discharges through the rarefied strata of the upper atmosphere, or may be due to a brush discharge (which see) across conductors carrying a high voltage.

Corrector Circuit.—A circuit added to land lines to correct their deficiency from the point of view of resistance, inductance or capacity.

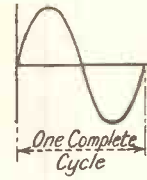
Coulomb.—A practical unit of quantity of electricity. It is equivalent to the quantity of electricity contained in 6,000,000,000,000,000,000 electrons. It is also defined as that quantity of electricity which a condenser of 1 farad capacity will store when its potential is raised from zero to 1 volt. A coulomb is equivalent to the quantity of electricity carried by 1 ampere per second.

Coulomb, Charles Augustin.—Born in France, 1736, died 1806. A distinguished French scientist who devoted his life to the study of electricity and magnetism amongst other things. Made a number of important discoveries. The practical unit of quantity of electricity is named after him.

Counter E.M.F.—(See Back E.M.F.)
Counterpoise.—(See Balancing Capacity.)
Coupled Circuits.—Separate circuits which are made to influence one another, so that a change in the strength of current in one circuit will produce a change in the E.M.F. in the other circuit.
Coupler.—A device which enables either the position or the distance between two coils to be varied at will.
Coupling.—See Coupled Circuits.
Cross Modulation.—Interference between two transmitting stations working on close-lying wavelength, so that both stations affect each other's modulation.
Crystals.—In wireless this means certain minerals of crystalline form which possess unidirectional conductivity of electrical currents (they will pass currents in one direction, but not in the opposite direction), and can thus serve as rectifiers of alternating currents and be of use as wireless detectors. Some crystals will work only with a polarising battery.
Crystal Characteristic.—A graph showing how the current through a crystal varies with the growth and the reversal of an applied E.M.F. Rectifying crystals show a non-symmetrical characteristic curve.
Crystal Circuit.—A wireless receiving circuit employing a crystal as a detector.
Crystal Control.—This is a frequency control with the help of a quartz crystal which has the peculiar ability of setting itself into mechanical oscillations when an alternating voltage is applied across its two opposite faces. The frequency of mechanical vibrations depends upon the dimensions of the crystal. This property is used for controlling the frequency of a circuit or checking it in the case of a transmitter. The quartz crystal is also used in electrical clocks.
Crystal Detector.—(See Crystals.)
Crystal Holder.—A piece of mechanism which can be regulated, used for keeping in position in respect of each other either a piece of crystal and a cat's whisker or two crystals.
Crystal Receiver.—(See Crystal Circuit.)
Cumulative Grid Rectification.—A method of valve rectification which is also referred to as leaky grid rectification. The input circuit to the detector valve is represented by a condenser with a grid leak either across it or in series with it. With this arrangement an effect is obtained which is somewhat similar to the anode bend detection. Charges accumulate faster on the grid than they can escape, owing to the high resistance of the grid leak which allows grid electrons to leak away slowly. This rate of leakage can be controlled by employing various values of components in question so that the whole thing forms a sort of timing leakage device. This is the usual method of rectification which is supposed to be better than the anode bend method and not as good as the push-pull method of rectification, from the point of view of quality of reproduction.
Current.—A flow of electrons from atom to atom of a conductor under the influence of an electro-motive force. The strength of the current is measured in amperes. An electrical current has three effects associated with its flow, the chemical effect, the heating effect and the magnetic effect (which see).
Current Density.—Direct currents flow uniformly throughout the interior of the conductor. There is a definite number of electrons, with a given strength of current, passing through the unit area of the cross section of the conductor. Current density can therefore be defined as the strength of current in amperes divided by the cross sectional area of the conductor in either square centimetres or square inches. In engineering the permissible current density for each type of conductor is defined and can be found in electrical engineering tables.
Current Transformer.—This is a transformer which enables a small current and a large voltage in the primary to be converted into a large current and a small voltage in the secondary, or *vice versâ*. It can be used for measurement purposes. The primary is connected in series with one of the mains and the secondary has a measuring instrument placed across it. In this manner it is not necessary to pass a large current through the meter.
Cut-off.—This refers to the ranges of frequency which a device will "cut-off," *i.e.*, fail to reproduce. Thus a loud speaker, used without a baffle, cuts off, as a rule, the lower frequencies, *i.e.*, the bass.



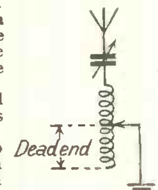
C.W.—Continuous wave.
Cycle.—A complete cycle of events or variations occurring in one second. In the case of alternating current one complete cycle means an E.M.F., or current starting at zero, gradually but quickly increasing to a maximum, and again decreasing to zero (half cycle). After that it reverses its direction, grows to a maximum in the reversed direction, and then decreases to zero again (end of cycle). The number of cycles per second constitutes the frequency of an alternating E.M.F. or current or electro-magnetic wave.



Cymometer.—This is a wavemeter due to Sir Ambrose Fleming in which the capacity and the inductances are varied simultaneously.

D

Damped Oscillations, or Damped Waves.—These are oscillations of current E.M.F. or waves, the amplitude of which steadily decreases till it is reduced to zero.
Damping.—This is measured by the ratio of the maximum amplitude during one half cycle to the maximum amplitude during the next half cycle. Used as a verb, it means manipulating the electrical constants of a circuit in such a way as to cause a rapid decrease in the successive amplitudes.
Db.—Abbreviated decibel (which see).
D.C.—Direct current.
D.C.C.—Double cotton covered (conductor).
Dead Beat.—Applies to measuring instruments in which the pointer is connected mechanically to some damping device in the form of an air piston or a controlling spring. With such a device there are no oscillations of the pointer, and it gives an immediate indication after every change in the value of the current or the E.M.F.



Dead End.—The portion of a tapped coil through which no current is flowing.
Decade Resistance, also referred to as Post Office box resistance, which consists of resistance tapped in multiples of 10 ohms. The resistance coils are connected to sockets, and connections are made with the help of plugs.
Deci.—A prefix indicating one-tenth of a unit.
Decibel.—One-tenth of a bel (which see).
Deci-neper.—One-tenth of a neper (which see).
Decoupling.—A method of connections made in order to prevent the passing back of energy from the output end to the input end of valve or receiver, *i.e.*, in order to prevent "feed-back."
Decrement, also referred to as the Logarithmic Decrement.—The latter is the natural logarithm of the ratio of the amplitudes of two successive damped waves (see Damping).
Degree of Coupling.—(See Co-efficient of Coupling.)
Demodulation.—This term is applied to a phenomenon taking place in a wireless receiver when a weak modulated induced E.M.F. is swamped by a much stronger induced E.M.F. on a close-lying interfering frequency and thus made inaudible. It is not correct to apply the term demodulation to rectification, *i.e.*, the action of detector valve.
Detection.—The separation of a high-frequency modulated current into its component high-frequency and low-frequency currents; the latter correspond to the microphonic currents.
Detector.—A device for carrying out detection in a wireless receiver. Detectors are divided into two classes—crystal detectors and valve detectors. It is not the crystal or the valve alone that carries out detection. Both do so in conjunction with the telephone or loud speaker windings which offer a low impedance to the passage of the low-frequency current.
Detector Valve.—A thermionic valve specially designed for detection purposes. Every thermionic valve will act as a detector, but the detector valve will perform this duty more efficiently than any other valve, as its characteristic is designed for the purpose.
Detuning.—Varying the tuning of the receiver so as to bring the tuning circuit into resonance with a slightly different frequency to that received.
D.F. Station.—Direction-finding station which helps shipping or aerial traffic to find their bearings by utilising direction-finding apparatus on board. Such stations sending out automatic signals are also called radio beacons.
Diagram, Theoretical.—A diagram indicating by means of conventional signs the method of connection of different components in a given circuit.

Diagram, Wiring.—This is a practical diagram showing the shape and position of every component in a receiving circuit and the actual position of each wire connecting the components.

Diaphragm.—A thin piece of metal or carbon which, in vibrating, will vary the strength of the current in the circuit in the case of a microphone, or produce sound waves, as in the case of head telephones or a loud speaker. The loud speaker diaphragm nowadays is usually in the form of a cone.

Dielectric.—An insulating substance.

Dielectric Absorption.—(See Absorption.)

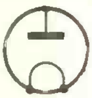
Dielectric Coefficient.—(See Capacity, Specific Inductive.)

Dielectric Loss.—Loss of electrical energy in the case of high-frequency currents, due to its absorption in the dielectric.

Dielectric Strength.—The term is used in connection with the ability of a dielectric to withstand the application of a high voltage without breaking down and letting a current go through. The dielectric strength of a material does not depend upon the thickness of the material (a thicker piece may have less dielectric strength than a thinner one), but on the nature of the material.

Difference of Potential.—This can be briefly defined as the difference in the number of electrons in surplus or in deficit in the atoms at two points. It is measured by the amount of work in ergs that has to be done in carrying a unit electric charge from one point to another. The difference of potential means that electrical energy can be converted into some other form of energy. In practice, difference of potential is measured in volts.

Differential Condenser.—This is a variable condenser with three sets of vanes. Two sets are fixed and the third set can be moved, so that its overlap takes place simultaneously with both fixed sets. While the overlap with one fixed set increases it decreases with the other. Therefore, while the capacity grows with respect to one fixed set, it diminishes in respect of the other fixed set. Such condensers are used in many a modern circuit.



Diode.—A two-electrode valve invented by Sir Ambrose Fleming.

Diode Rectification.—Rectification carried out with the help of a two-electrode valve. In wireless reception, *i.e.*, detection, this arrangement is not as efficient as others. This method of rectification is used largely in rectifying alternating current for supply purposes. The method is also referred to as half-wave rectification.

Direct Coupling.—A form of inductive coupling in which the two coils are also connected by a metallic conducting path. This method is used often for connecting the secondary aerial circuit to earth by connecting with a piece of wire one end of the secondary coil to the respective end of the primary coil. (See also Auto-transformer.)

Direct Current.—A unidirectional flow of electrons under the influence of a constant (unchanging) E.M.F., such as obtained from cells or a dynamo. Abbreviated D.C.

Direct Ray.—A term used in transmission to indicate the portion of the radiated electro-magnetic waves which proceeds parallel to the ground following its curvature, as distinguished from the waves which shoot up to be reflected back to earth by ionised layers in the atmosphere.

Directional Aerial.—An aerial which transmits or receives in one direction better than in another. An inverted L aerial possesses this characteristic. The Bellini-Tossi aerial (which see) is also of this type.

Direction Finder.—A combination of a directional aerial with a wireless receiver.

Dis.—An abbreviated term for disconnection. A break in the continuity of a circuit.

Discharge.—When two electrically charged conductors are either brought very close together or are connected by a wire they will share their surplus or deficit of electrons in their surface atoms by allowing electrons to pass from the conductor having a surplus to the conductor having a deficit, or from a conductor having a larger surplus to a conductor having a smaller surplus of electrons, or from a conductor having a smaller deficit to a conductor having a larger deficit of electrons. In other words, electrons will pass from a conductor having a higher potential to the conductor having a lower potential. This is known as discharge. After discharge two conductors carrying equal but opposite charges become neutral.

Disruptive Discharge.—When the difference in potential between two charged conductors separated by a dielectric is pushed too high, a spark will pass from one conductor to another, either through the air or through the dielectric which thus has broken down.

Distortion.—Departure from true-to-life reproduction of speech and music in a wireless receiver and loud speaker, due to numerous causes which alter the manner of variation (the wave form) of the E.M.F.'s and currents in the receiving circuit. This is often due to overloading of valves (wrong voltages applied all round) and pushing the reaction too far.

Distributed Capacity.—A condenser in its simplest form is represented by two conductors separated by a dielectric. Two insulated wires lying side by side will therefore form a condenser of sorts. This is the reason that there is capacity between each pair of turns in a coil. This capacity, which is called the self-capacity of the coil, is distributed throughout the length of the coil, and is spoken of as the distributed capacity. It is equivalent to having a small condenser across the coil (concentrated capacity), so that a coil does not only provide inductance in a circuit, but also supplies a certain amount of capacity. There is a certain amount of loss of electrical energy in the insulation between the turns.

Double Reaction.—There are receiving circuits in which two reaction coils are used, coupled to the grid circuit of the first high-frequency valve and to the grid circuit of the detector valve simultaneously.

Down Lead.—This is the wire which connects the aerial wire to the receiver.

D.P.—Abbreviation for double pole (switch).

D.P.D.T.—Abbreviation for double pole double throw (switch).

D.P.S.T.—Abbreviation for double pole single throw (switch).

Drive Circuit.—A transmitting circuit which controls the frequency of oscillations with the help of a quartz crystal or a vibrating tuning fork. The latter can be made electrically to vibrate continuously on the principle of the trembler of the electric bell.

Drop of Potential.—(See Voltage Drop.)

Dry Battery (see also Battery, Dry).—A battery made of a number of dry cells connected in series and provided with a number of tapping sockets giving different voltages.

Dry Cell.—(See Battery, Dry.)

Dry Rectifier.—A term used in connection with metal rectifiers.

D.S.C.—Double silk covered.

D.T.—Double throw.

Dual Amplification.—A reflex circuit using a single valve for both high-frequency and low-frequency amplification.

Dull Emitter.—A thermionic valve the filament of which does not glow. In other words, it provides an adequate electron emission at a low temperature.

Dumb Aerial.—An artificial aerial used in wireless Morse transmission in conjunction with the radiating aerial.

Dummy Aerial.—(See Artificial Aerial.)

Duplex-Telephony.—A system of telephony allowing the sending of speech in both directions simultaneously, so that a normal conversation can be carried out between two distant points.

Dynamic Characteristic of a Valve.—A characteristic graph plotted under working conditions when alternating potentials are being applied to the grid of the valve as distinguished from those described in *Characteristic Curve* (which see), in which the relation between the various quantities are established when the valve is not connected to a source of oscillation (static characteristic).

Dynamic Loud Speaker.—(See Moving Coil Loud Speaker.)

Dynamo.—An electrical machine which provides a direct E.M.F. It consists of a magnet system supplying a constant magnetic field. In this field is rotating an armature in the form of an iron slotted drum, the slots of which carry a system of conductors. The conductors are connected to a commutator (which see). The contact with an outside circuit is made through carbon brushes resting upon the commutator.

Dynatron.—A thermionic valve in which the current is the difference in the number of electrons passing from the filament to the anode and the number of electrons leaving the anode in a form of a secondary emission. This is a phenomenon which also occurs in a screened-grid valve. In the case of these two valves the filament electrons reach the anode with such a force that they knock out of it other electrons which are called *secondary electrons.* The electrons knocked out from the anode flow in the opposite direction to the electrons arriving from the filament, and by repelling each other reduce the current through the valve.

Dyne.—This is a unit of force in the C.G.S. system. One dyne is a force which, when applied to a mass of 1 gramme, will communicate to it an acceleration of 1 centimetre per second per second.

E

Earth.—In wireless the name earth is applied to the contact of a receiving circuit with the ground. Moist ground or water provides a better electrical contact than dry or frozen ground. The wire connecting the receiver to earth should be as short as possible and fairly thick; in other words, the resistance of earth connection must be low. Electronic tides take place in the receiving aerial and the earth, which can be considered as an inexhaustible source of electrons, as its number of surface atoms is vast in comparison with the number of surface atoms in a conductor, has a function of maintaining the electronic tides. When electrons are receding from the aerial or from a condenser plate, the earth will accept any number of electrons. When electrons are rushing towards the aerial the earth will provide the necessary numbers for this purpose. Thus the earth helps the electro-magnetic wave to keep the electrons in the aerial system on the move, now in one direction, now in another. If a direct contact with earth cannot be obtained a water pipe which leads to earth will provide an excellent alternative, provided a clean joint is made between the pipe and the connecting wire. *A gas pipe is not only worse than useless for this purpose, as its resistance is high, but it is highly dangerous on account of the gas in the pipes, which may be ignited by an electric spark.* A counterpoise is another alternative to earth, although not as good.

Earth Conductivity.—Earth, which is a conductor, like any other conductor has resistance that can be measured. The resistance of dry earth is higher than that of moist earth. Earth conductivity is the reciprocal of earth resistivity. An electro-magnetic wave which spends its energy in moving electrons in a conductor it encounters has to move electrons in the ground, as in any other conductor. For this reason a wave which follows the curvature of the earth wastes part of its energy upon the ground electrons, and for this reason gets weakened or attenuated with distance. It is possible to calculate this attenuation at various distances, and to estimate the attenuation factor which indicates the rate of decrease of the wave's amplitude in terms of the distance from the point of radiation. The earth's conductivity is greater over sheets of water than over pastoral land, and the conductivity over forest land is worse than that over pastoral land.

Earth Potential.—The electrical potential of earth is presumed to be zero. A negative potential is higher than the earth potential, and a positive potential is lower than the earth potential. The reason for this is that the earth being such a vast mass of surface atoms, by the time it shares its charge amongst all of them, each atom will share in an infinitely small charge. Thus for all practical purposes we can take the earth as being electrically neutral, even when it is absorbing or delivering electrons. A *negatively* charged body has a surplus of electrons in each atom. When connected to the ground it will give up its surplus to earth, which will accept any number of electrons, and thus, after a flow of electrons from the negatively charged body to earth, the body will become neutral. Similarly, a *positively* charged body having a deficit of electrons will compensate itself for this deficit at the expense of the earth and electrons will flow from earth to the positively charged body.

Earth Screen.—(See Balancing Capacity.)

Ebonite.—A hard, insulating material consisting, amongst other things, principally of rubber and sulphur. It can be sawn, drilled and generally worked mechanically. Used for receiver front panels and terminal boards.

Echo.—Reflection of sound waves from a hard surface, or that of electro-magnetic waves from an ionised layer.

Echo Room.—A term used in broadcasting to indicate the place where echoes are produced artificially in order to give a more life-like effect to broadcasting.

Eddy Currents. — These currents are induced by an alternating magnetic field in metallic solid parts of machines where, in eddying, they cause an increase of temperature which is communicated to the useful conductors with a consequent increase of their resistance and the lowering of the resistance of insulating substances surrounding the conductors. To avoid this all solid parts in which such currents can be produced are laminated so that the continuous path is interrupted at very frequent intervals, and the induction is confined transversally to a very thin sheet of metal, separated by a thin layer of air or insulation from the next sheet.

Effective Height of Aerial.—Theoretically the higher the aerial, within practicable limits, the better reception can one obtain with it. But the height of an ordinary aerial does not prove to be all effective. The effective height is always less than the real height. This effective height depends upon the shape of the aerial, its location and a number of other items.

Effects Studio.—A studio for production of audible sound illustrations in a play, such as wind, rain, all sorts of noises, etc.

Efficiency.—The ratio of output to input. This ratio is multiplied by 100 in order to express the efficiency as a percentage.

Electric Field, also referred to as Electrostatic Field.—The space around a charged body undergoes a certain modification, as in the case of a magnetised body. If this space is explored in the neighbourhood of, say, a charged sphere, it is found that there are radial strains in the ether all round it, strains which will cause, for instance, a very light body, such as a pivoted straw, to take up a definite direction. When such a space is mapped out, with the help of pivoted straws, it proves to be consisting of a number of lines of force stretching around the electrified body in all directions. The space occupied by these lines of force is called the electric field. It is assumed that each electron and proton has an electric field permanently associated with it. When a body is neutral the electronic and protonic fields contract within the atoms of the body, and there is no external field to be found. But when there is an excess or a deficit of electrons (predominance of protons) these fields become apparent. An electric field may exist in the ether on its own, without an electrified body, as a part of the electro-magnetic wave. In this case there is always associated with it a magnetic field situated at right angles to the lines of force of the electric field. An electric field will react upon the electrons in a conductor and will cause them to move, on passing the conductor, either by repulsion or attraction, in accordance with the direction of the lines of force.

Electrode.—This name is applied to plates in primary or secondary cells or the plates in an electrolytic bath. The internal conductors within a thermionic valve, a photo-electric cell, or a cathode ray oscillograph, are also referred to as electrodes.

Electro-dynamic Microphone.—A delicate coil of wire is attached to a light diaphragm and is connected to an amplifier. A magnetic field is provided in the space in which the coil can vibrate. When the diaphragm begins vibrating under the influence of sound waves, the coil vibrates with it and its conductors cut the lines of force of the magnetic field. A varying current is thus induced in the coil and is amplified in the ordinary way. Such an arrangement is used as a fairly sensitive microphone. There is an earlier type working on a similar principle and called the *magnetophone.*

Electrolysis.—An application of the chemical effect of electrical currents, which consists in breaking up the molecules of a chemical solution into its constituent atoms and depositing these atoms upon the electrodes. Electro-plating is the commercial application of this.

Electrolyte.—The liquid solution inside an electrolytic bath. Also the liquids inside a primary cell or accumulator.

Electrolytic Condenser.—A special type of condenser of a form reminiscent of a primary cell in which polarisation is produced on purpose, and the polarised plates, which are thus completely insulated, form the plates of the condenser. With this type of condenser it is possible to obtain a very large capacity with a very small bulk, as compared to the usual type of condenser.

Electrolytic Rectifier.—This is an electrolytic cell which will allow a current to pass through in one direction only, and thus possesses unidirectional conductivity. It is also called the *nodon valve.*

Electro-magnet.—An electro-magnet is a coil of wire mounted upon an iron core. When a current flows through the coil a magnetic field is produced inside the coil and the iron is magnetised by induction. It will remain magnetised all the time the current is flowing. When the current ceases the magnetism disappears (not altogether, a little is left), as iron does not remain magnetised permanently.

Electro-magnetic Induction.—When a closed conductor moves with considerable speed in a magnetic field so as to cut its lines of force at right angles, or a magnetic field moves similarly near a conductor, an E.M.F. is induced in the conductor and a current will flow in the closed circuit. This phenomenon is called electro-magnetic induction.

Electro-magnetic Units.—These units are based upon the C.G.S. system of units, and their starting-point is the force exercised between two magnetic unit poles. From this other units are deduced.

Electro-magnetic Wave.—(Also referred to as wireless wave.)—All disturbances in the ether, such as light, heat, wireless waves, cosmic rays, etc., are of the same nature and are propagated in space with the same speed of 300,000,000 metres or 186,000 miles per second. Such waves are distinguished by their wavelengths. An electro-magnetic wave, as its name implies, consists of two varying fields: the electric field and the magnetic field. Within a quarter of a wavelength (if the wavelength of the radiated wave is a mile, then within a quarter of a mile) from the transmitting aerial these two fields created in space by the currents flowing in the aerial pulsate to and fro, in all directions around the aerial wire. Beyond that distance it is found that they are shaken off into space and start going away with the speed mentioned above. While within the quarter of wavelength distance the two fields are a quarter of a cycle out of step (phase), but when actually travelling in space they are in step so that both the electric and the magnetic fields reach their maxima simultaneously. They grow together, diminish together, reverse their direction together, and if one should disappear, the whole wave disappears. Normally, the electric field is vertical and the magnetic field is horizontal. The electric field acts upon the electrons in an open outdoor aerial or an open indoor aerial. The magnetic field acts upon the frame aerial.

Electro-motive Force.—Abbreviated as E.M.F. An electro-motive force is the force which causes electrons to migrate round the circuit. It is created by converting some form of energy (mechanical, chemical, thermal, etc.) into electrical energy which manifests itself in that when this energy is applied to a circuit, one point of the circuit is made poor in electrons and the other rich in electrons. Thus electrons, as it were, are shifted to one side and have an incentive to go round the circuit from the point of surplus to the point of deficit. Since this difference in the number of electrons at the two points is maintained, a current will flow continuously round the circuit all the time the E.M.F. is present. The E.M.F. is also measured by the amount of work in ergs that has to be expended in moving a unit electrical charge round the circuit. The practical unit of measurement is the volt. The E.M.F. is also sometimes referred to as electrical pressure, electrical tension, or simply voltage.

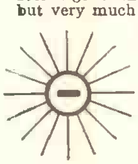
Electron.—This is a particle of pure electricity, corresponding to the old idea of negative electricity. Although it is far to minute to be seen even with the most powerful microscope, it has been carefully measured and a great deal is known about it.

The mass of an electron is 9×10^{-28} grammes (nine over 1 × by 28 noughts).

The quantity of electricity contained in it (or its charge) is $4{\cdot}774 \times 10^{-10}$ electro-static units.

The radius of an electron is $1{\cdot}87 \times 10^{-13}$ centimetres.

It is larger than the proton (a particle of positive electricity) but very much lighter. It used to be known as the *beta particle*, and a stream of electrons in a cathode ray oscillograph has been known as the *cathode ray*. Every atom has a definite number of electrons which is equal to the number of protons in the atom. Electrons are to be found inside the atomic nucleus (cementing electrons) and also outside within the boundaries of the atom. These outside or extra-nuclear electrons are called "planetary electrons"



Each planetary electron rotates around the nucleus in an orbit of its own, and can pass under the influence of an outside force from one orbit to another, and even leave the atom altogether. The *atomic number* (see Atom) is equal to the number of "planetary" electrons. The number of "cementing electrons" within the nucleus is equal to the difference between the atomic weight and the atomic number. Electrons repel each other and an electron will attract a proton. A rapidly moving electron has two fields associated with it, the electric and the magnetic field. The electric field is normally part and parcel of the electron and the magnetic field is due to the motion of the electron, as a moving charge constitutes what we know as electric current (see Magnetic Effect of Electrical Currents). A body is said to be negatively charged when its surface atoms have a surplus of electrons over and above their normal quota. A body is said to be positively charged when it has a deficit of electrons, and therefore has a predominance of protons. When the number of electrons and protons in an atom is equal the atom is electrically neutral, as each electron is balanced by its respective proton. It is the electron that is responsible for all electrical phenomena. The proton plays a passive *rôle*.

Electro-statics.—This name applies to the portion of electrical science dealing with charges at rest (static charges).

Electro-static Loud Speaker.—(See Condenser Loud Speaker.)

Electro-static Capacity.—(See Capacity.)

Electro-static Coupling.—Coupling of two circuits by means of a condenser so that one circuit influences the other through condenser charges and discharges.

Electro-static Field.—A stationary electric field around an electrically-charged conductor.

Electro-static Induction.—An electronic tide produced by a charged body in a neutral body at a distance, due to repulsion of electrons or attraction of protons.

Electro-static Units.—This system of units is based upon the G.C.S. system and the electrical units are derived from calculating forces exercised upon a *unit electric charge*.

E.M.F., abbreviated Electro-motive force.

Emission.—When a metallic conductor is heated it emits electrons into space from the surface atoms. This is referred to as emission of electrons. The emission depends upon the temperature of the body. This is the basic principle of the thermionic valve action in which the heated filament is the source of emission. Such emission can be obtained with a lower temperature if the conductor is coated with a substance rich in electrons (thoriated filaments). (See Molecular Vibrations.)

Endodyne.—A receiver containing a source of local oscillations for the purpose of beat reception.

Energy.—A body can perform work in virtue of its position (a stone placed on the edge of a roof and smashing another stone in its fall). This kind of energy, which is really due to gravity, is called *potential* energy. A wound-up watch spring also possesses potential energy on account of displacement of its parts and its elasticity. A stone kicked by a man will also do work and is said to possess *kinetic* energy. This is energy communicated to a body by means of an outside force. Energy is propagated through space in the form of radiations. An electro-magnetic wave possesses energy and on reaching matter will do work in shifting its electrons (wireless), accelerating the motion of atoms and molecules (heat) and in producing chemico-electrical effects in visual organs (light). This energy associated with electro-magnetic waves is supposed to reach us in definite quantities called *quanta*. (See Quantum.)

Erg.—A unit of work based upon the C.G.S. system of units. It is defined as the amount of work performed by a force of one dyne acting over a distance of one centimetre.

Ether.—The name given to the medium which is supposed to pervade all space and matter, the exact nature of which is as yet unknown and whose existence is still in doubt. There are several scientific reasons, however, which lead to the belief that such a medium exists. It may be that the electron and the proton are merely "solidified" or localised ether waves and this theory has been lately gaining ground as it has been found that the electron is definitely associated with electro-magnetic waves. The ether possesses two properties, the nature of which is not yet clear; the electric property which manifests itself in the form of electric fields akin to strains in a medium and the magnetic property which is the magnetic field. In an ether disturbance these two combine into what we call an electro-magnetic wave.

Ether Waves.—(See Electro-magnetic Waves.)

Eureka Wire.—A wire used in making resistances. It is an alloy of copper and nickel which possesses a high resistance per unit length. Its resistance is only slightly increased with the increase of temperature.

Excitation.—Communication of electrical energy to a circuit.

Exponential Horn.—An acoustic horn of a loud speaker, a gramophone, etc., which gradually increases its diameter with the increase in length in accordance with a certain mathematical law, *i.e.*, in a definite proportion.

F

Fading.—Electro-magnetic waves are divided into two groups, one called the direct ray, which proceeds along the surface of the ground and follows its curvature, and the other called the reflected ray, which undergoes reflection from the Heaviside layer (which see). The latter is not uniform in its shape, which varies from moment to moment. Sometimes a reflected wave interferes with the direct ray wave. All this may cause a diminution of the received signal strength so that the reception is now strong and now faint. This is called fading of signals.

Fan Aerial.—An aerial in which the wires are arranged fanwise.

Farad.—This is a unit of capacity. A condenser is said to possess a capacity of one farad when it will store one coulomb of electricity with one volt difference of potential applied across its plates. A farad is too large a unit for wireless work and therefore in wireless we use microfarads (a millionth part of a farad) or even micro-microfarads (a millionth of a millionth part of a farad).

Faraday, Michael.—Born 1791, died 1867. A famous English physicist who made important discoveries in the field of electrical engineering. The unit of capacity is named after him.

Feed-back.—Another name for reaction.

Field Strength.—The amount of energy possessed by an electro-magnetic wave radiated from a transmitting aerial diminishes as we go further and further away from the aerial. The listener who wishes to ascertain what sort of strength he is receiving from a given transmitter can measure the induced voltage in millivolts in a special aerial made of one metre effective height. Thus, he is measuring the intensity of received signals, or as it is called, the field strength, due to a given transmitter in millivolts per metre.

Field Winding.—A term referring to the coil mounted on an electro-magnet which forms part of the magnetic system of a generator and provides the magnetic field.

Filament.—A thin wire of metal inside an electric bulb or a valve through which a current is made to flow in order to raise the temperature of the filament to white heat in the first case, and in order to produce an emission of electrons in the second case.

Filament Battery.—This is the battery or cell which is connected across a valve filament. It is also called low-tension battery or cell, and is abbreviated as L.T. battery.

Filament Circuit.—This is the circuit which consists of the filament of a valve, a filament rheostat and the L.T. battery together with the connecting wires. A voltmeter across the filament proper and an ammeter in series with the filament and the rheostat may be also included in this circuit, for measuring purposes.

Filament Current.—The electrical current flowing through the filament of a valve.

Filament Current Control.—The strength of the current flowing through a valve filament is controlled by means of a variable resistance connected in series with the filament. This resistance is called the filament regulator, filament rheostat or simply filament resistance.

Filament Emission.—(See Emission.)

Filament Regulator.—(See Filament Current Control.)

Filament Resistance.—A term that has a double meaning. The filament resistance is the resistance of the filament which depends upon the resistivity of the material of which the filament is made, its length and its cross-sectional area. The filament regulator which is connected in series with the filament is also referred to as filament resistance.

Filter.—A selective circuit comprising coils, condensers and resistances which can be manipulated and adjusted so as to select a certain range of wavelengths or reject certain wavelengths.

Fixed Resistor.—A component possessing a certain amount of fixed resistance that cannot be varied as in a rheostat.

Flat Tuning.—A receiver is said to possess flat tuning when a station can be heard over a wide range of movement of the condenser dial.

Flux, Magnetic.—The total number of lines of force emanating from a pole.

Flux Density.—The number of lines of force per unit area, the area being taken at right angles to the direction of the lines of force. Flux density in air is different to that in a magnetic material, such as iron, with the same M.M.F. giving rise to it.

Foot-pound.—This is the unit of work on the F.P.S. system of units.

Forced Oscillations.—Oscillations in a circuit produced by some external source of oscillations, having a frequency different from the natural frequency of the circuit as determined by its inductance and capacity.

Form Factor.—The form factor of an alternating E.M.F. or current is the ratio of the root mean square value to the mean value throughout a half-cycle. In the case of a pure sine wave it is 1·111.

Former.—A cardboard, ebonite, wooden or fibre frame on which a coil or resistance wire is wound. The material must be rigid enough so that the shape of the frame is not altered with atmospheric conditions or increase of temperature. From this point of view cardboard is the worst material to use.

Four-electrode Valve.—A valve possessing a filament, an anode and two grids. A typical example is the screened grid valve.

Frame Aerial.—An aerial consisting of a number of turns of insulated wire mounted upon a wooden frame. It responds to the magnetic field of the electro-magnetic wave and possesses marked directional properties. In the case of portable and transportable receivers the frame aerial is hidden within the cabinet and the latter is usually mounted upon a turntable so that the set can be rotated.

Free Grid Bias.—(See Automatic Grid Bias.)

Free Oscillations.—Oscillations taking place within a circuit with the natural frequency of this circuit as determined by its inductance and capacity. There is no external source influencing them as in the case of forced oscillations, except a directly applied alternating E.M.F.

Frequency.—This term refers to the rapidity of variations of alternating currents, alternating E.M.F.'s and electro-magnetic waves. The frequency of an alternating quantity is the number of complete cycles of events that takes place each second. We speak therefore of an alternating current having so many cycles per second—1,000 cycles are called a kilocycle.

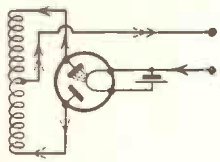
There is a definite relation between wavelength of an electro-magnetic wave and frequency. Since all electro-magnetic waves travel with the same speed of 300,000,000 metres per second the length of the wave is that speed divided by frequency. Thus:

$$\text{Wavelength} = \frac{300{,}000{,}000}{\text{frequency}} \text{ metres and}$$

$$\text{Frequency} = \frac{300{,}000{,}000}{\text{wavelength}} \text{ cycles per second.}$$

Frequency Modulation.—A method of modulation involving the shifting of frequency of a carrier wave.

Full-wave Rectification.—Rectification by means of a rectifying valve possessing a single filament and two anodes. During each half-cycle each anode is made alternately negative and positive, so that each anode in turn attracts electrons each half cycle. In this way each half of the current wave gets rectified, instead of only one-half being rectified and the other half of the cycle being wiped out, as in the case of two-electrode valve. This is made possible by connecting a tapped coil across the two anodes, this tapping and a lead from the filament providing a unidirectional output.



Fundamental Frequency.—The frequency of a fundamental wave.

Fundamental Wave.—A wave of a complex form can be resolved into a basic or fundamental wave and a number of harmonics. Each harmonic has a frequency which is a multiple of the fundamental frequency.

Fuse.—A piece of wire of predetermined thickness and melting point is placed across the terminals of a porcelain holder or is enclosed in a glass bulb. When the current reaches too large a value the fuse wire melts and the circuit is broken. This is used as a safety device in all mains receivers and supply mains.

G

Galena.—A mineral crystal of lead sulphide (PbS) used as a detector in wireless reception. The crystal is of cubic form and is of leaden grey colour.

Galvanometer.—An electrical *indicating* instrument of very high sensitivity which is used for detecting the flow of electrical currents in a circuit and for fault finding (continuity tests). It is extensively used with a mirror reflector upon the suspension thread for indicating currents of very small magnitude. In its simple form it consists of a magnetic needle placed horizontally in the centre of a comparatively large vertical coil through which a current is made to flow.

Ganged Condensers.—A number of condensers are mounted upon a single spindle so that all the condensers can be turned simultaneously by a single handle. These condensers are connected across matched coils so that a number of tuning circuits can be adjusted simultaneously. Such an arrangement saves having a large number of tuning knobs in a receiver.

Gap Choke.—An iron-cored coil used in the low-frequency circuit which has an air gap in the core. The presence of the air gap ensures that the inductance of the coil will vary uniformly with changes of current flowing through the coil.

Gauss.—This is a unit for measuring flux density. One gauss is one line per square centimetre. Since the unit of flux is one maxwell which is one line of force, we can say that a gauss is one maxwell per square centimetre. The gauss is an electro-magnetic unit based upon the C.G.S. system.

Gauss, Karl Friedrich.—Born 1777, died 1855. A distinguished German mathematician who devoted a great deal of his time to study of magnetism. The unit of flux density is named after him.

Generator.—An electrical machine which converts mechanical energy (provided by some form of prime-mover such as a steam engine) into electrical energy, viz., a dynamo and an alternator.

German Silver.—An alloy of copper, nickel and zinc.

Gilbert.—This is a unit for measuring magneto-motive force. A gilbert is the M.M.F. produced by $\frac{4\pi}{10}$ ampere-turns. π equals 3·1416.

Gilbert, William.—Born 1544, died 1603. A distinguished scholar and contemporary of Queen Elizabeth, who devoted his time, among other things, to study of magnetism. The unit of M.M.F. is named after him.

Gramme.—This is a unit of mass on the C.G.S. system and is one-thousandth part of the mass of a piece of platinum kept at the Archives of Paris.

Gramophone Pick-up.—A piece of apparatus consisting of a vibrating armature (a piece of iron) placed in the centre of one or two coils of wire mounted upon an iron core clamped to a permanent magnet. The gramophone needle is attached to the armature. When the needle, in following the sound track of the rotating record, vibrates it causes the armature to vibrate as well, and the vibrating armature induces currents in the coils. These currents are amplified by the receiver and are made to influence the loud speaker.

Grid.—A term applied to a valve electrode. In a three-electrode valve the grid which is made in the form of a thin spiral is placed around the filament and is itself surrounded by the anode. Its function is to control the flow of electrons through the valve.

Grid Bias.—A permanent charge communicated to the grid of a valve by connecting it to one side of a grid bias battery or obtaining its potential *viâ* a resistor. The biasing potential serves as the foundation upon which all future grid potentials will be superimposed. Since the potential of the grid influences the number of electrons passing from the filament to the anode, what a grid bias means is that we start working the valve with a definite anode current as determined by the grid and the filament temperature, before the valve is influenced by aerial potentials, and can thus choose the best possible working current for a given value.

Grid Circuit.—The circuit connected between the grid and the filament of a valve. It forms the input circuit to the valve.

Grid Condenser.—A condenser of fixed capacity, as a rule, connected in the grid circuit. When connected in the grid circuit of a detector valve its function is to carry out the rectification changes. When connected between the grid of a valve and the anode of the preceding valve it separates the grid from high-tension supply of the preceding valve.

Grid Control.—A term used in transmission. The grid controls the amplitude of the high-frequency oscillations in the aerial by superimposing upon them the microphonic pulsations of current applied to the grid circuit and thus modulates the aerial current.

Grid Current.—When the grid has a positive charge it draws some of the electrons passing from the filament to the anode upon itself by attraction, and these electrons flowing in the grid circuit constitute the grid current. As a rule this current is very small and is measured in micro-amperes.

Grid Leak.—A fixed resistance of the order of a few million ohms which is used as a high-resistance path for the leakage of electrons from the grid circuit. It serves as a sort of a timing device determining the rate of electrons leakage.

Grid Potentiometer.—A variable resistance connected across the low-tension accumulator for the purpose of biasing the grid of a valve. This arrangement is used in anode bend rectification.

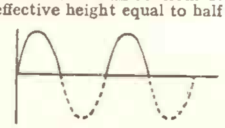
Grid Rectification.—(See Cumulative Grid Rectification.)

Ground.—An American term for earth.

Ground Ray.—(See Direct Ray.)

H

Half Wavelength Aerial.—A term used in transmission. It indicates an aerial having an effective height equal to half the wavelength of the radiated wave.



Half Wave Rectification.—Rectification with the help of a two-electrode valve in which only half the cycle of current variations passes through the valve, the other half being wiped out on account of the unidirectional conductivity of the valve.

Hand Capacity.—In some short-wave receivers it is possible to alter the adjusted tuning of the circuit by merely bringing one's hand near the receiver. The hand alters the capacity of the set in respect to earth. This effect is known as the hand capacity effect. Hand capacity can be avoided to some extent by the use of long extension handles attached to all the tuning knobs.

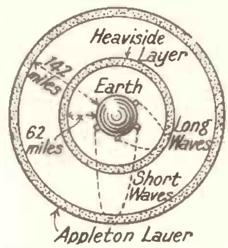
Hard Valve.—A valve with a practically complete vacuum inside.

Harmonics.—(See Fundamental Wave.)

Heat.—(See Molecular Vibration.)

Heater (of valve).—Also referred to as the cathode heater. In a valve the emission of electrons takes place from a heated conductor. It is not necessary to pass an electric current through the emitting electrode itself; it can be heated indirectly. For this reason, in the case of indirectly heated A.C. mains valves, the cathode which takes the place of the filament of an ordinary valve, from the point of view of electron emission, has inside it and insulated from it electrically a heating element which is called the heater. This heater warms up the cathode and raises its temperature to the required limits.

Heaviside Layer (also referred to as Kennelly-Heaviside Layer).—This is a layer of ionised (electrified) atoms in the molecules of the upper atmosphere similar to the Appleton layer. It is to be found about sixty-two miles above the earth surface. The sun rays are responsible for its ionisation. Its function appears to be that of reflecting back to earth the long waves (see wireless waves, classification of), while the Appleton layer reflects the short waves which are able to pass the Heaviside layer without reflection, *i.e.*, without being turned back to earth.



The shape of this layer, which completely surrounds the earth in the form of a spherical shell, varies with the hour of the day and the season of the year. Hence the difference in the reception results between day and night and summer and winter.

Heaviside, Oliver.—Born 1850, died 1925. A noted English scientist who spent a considerable part of his life on work in telegraphy and telephony. It has been said that: " Heaviside exemplifies a rare case of the combination of great theoretical and mathematical powers with a bias of mind which was strongly practical." He simplified Maxwell's electro-magnetic theory and made high-speed telegraphy what it is to-day. The layer is named after him.

Henry.—This is the practical unit of self-inductance. A coil is said to possess a self-inductance of 1 henry when a current flowing in it and changing in magnitude at the rate of 1 ampere per second will induce in another coil an E.M.F. of 1 volt. The henry is too large a unit for practical purposes, and for this reason in wireless self-inductance is measured in millihenries or microhenries.

Henry, Joseph.—Born 1797, died 1878. A noted American physicist, well known for his work on electro-magnetism. The unit of self-inductance is named after him.

Hertz.—This is a unit of frequency. One hertz equals one cycle per second. One thousand cycles per second is called a kilohertz.

Hertz, Heinrich Rudolf.—Born 1857, died 1894. A famous German physicist who, in following up Maxwell's work, discovered the existence of electro-magnetic waves and associated light with these waves. The term Hertzian waves still persists in connection with electro-magnetic waves. The unit of frequency is named after him.

Hertzian Waves.—Another name for electro-magnetic waves. The existence of these waves has been predicted mathematically by Maxwell, discovered by Hertz, and applied in practice by Marchése G. Marconi.

Heterodyne.—Production of a beat frequency by the interaction of two close lying frequencies. The term superheterodyne takes its name from this.

Heterodyne Interference.—This is the interference between two broadcasting stations transmitting on close lying frequencies so that their waves combine into a beat wave producing in the receiver a beat or low-frequency note.

Heterodyne Reception.—(See Beat Reception.)

Heterodyne Wavemeter.—A wavemeter using the heterodyne principle for measuring wavelengths. When the measured source of oscillations and the wavemeter's own oscillations combine and fail to produce a beat note, both frequencies and therefore wavelengths are equal.

H.F.—Abbreviated *high frequency*.

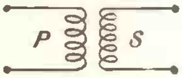
High Frequency.—Frequencies above 15,000 cycles per second.

High-frequency Amplifier.—The pre-detector part of a receiving circuit containing amplifying stages, which deal with high-frequency voltages before rectification.

High-frequency Choke (air core choke).—A coil of wire used for amplification purposes in high-frequency circuits. (See Choke.)

High-frequency Resistance.—This is the resistance offered by a conductor to the passage of a high-frequency current. It is higher than ordinary resistance offered by the same conductor to a direct current of the same magnitude.

High-frequency Transformer.—A transformer without an iron core, also called an air core transformer, used in high-frequency amplifying circuits. Its action is not the true transformer action, as energy is being passed on to the secondary, not only inductively, but also through capacity action. As a rule in a high-frequency transformer the primary turns are the same as the secondary turns in number. The H.F. transformer windings are sometimes tuned with the help of variable condensers connected across the windings.



High-pass Filter.—A filter circuit which will pass frequencies above a certain value.

High Tension.—A term applied to the anode battery voltage of a receiver. This is a very misleading term, as in electrical engineering high tension means thousands of volts. In wireless, presumably, 150 volts is very high as compared with the two volts in " the low-tension circuit."

High-tension Battery.—Anode dry battery or anode bank of accumulators for providing the high-tension voltage.

Honeycomb Coil.—A coil which resembles in its appearance a honeycomb. It is usually of the plug-in type, and is used for tuning purposes and generally as a high-frequency coil.

Horseshoe Magnet.—A magnet made in the shape of a horseshoe.

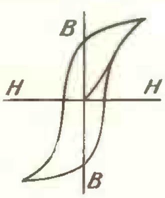
Hot Wire Ammeter.—An ammeter used mainly for measuring high-frequency oscillating currents. It consists of a wire which is heated by the passage of current through it and which on expansion with the help of an ingenious arrangement of threads, pulley and spring, causes the pointer to move in proportion to the strength of the current flowing through it. Since the heating effect of electrical current does not depend upon the direction of the current, it will work equally well with D.C. and A.C.

H.T.—Abbreviated *high tension.*

Hydrometer.—An instrument for measuring the specific gravity of accumulator acid and other liquids.

Hysteresis (Magnetic).—A difference in the cycle of magnetisation and demagnetisation of iron, resulting in loss of energy and causing distortion in the low-frequency circuit of a receiver.

Hysteresis Loop.—A graph showing the relation between magnetising force and flux density over a complete cycle of magnetisation and demagnetisation.



I

I.C.W.—Stands for *interrupted continuous wave.*

Impedance.—Opposition offered to the passage of an alternating current by a circuit. This opposition is a combination of ordinary resistance, self-inductance, and the capacity of the circuit. It is denoted by the symbol Z.

In Phase.—Alternations taking place in step. Two quantities are said to be varying in phase if they are both in the same direction and both reach their zero, their intermediate and their maximum values at the same time.

Indirectly Heated Cathode.—(See Heater.)

Indirect Ray.—Wireless waves reaching a receiving aerial after being reflected either by the Heaviside or Appleton layer.

Induced Current.—An electric current that flows in a closed circuit under the influence of a varying magnetic field the lines of force of which cut the conductors of the circuit at right angles.

Induced E.M.F.—An E.M.F. produced across a circuit the conductors of which are being cut by the lines of force of a varying magnetic field.

Inductance.—Another name for coefficient of *self-induction* (which see). Symbol L.

Inductance Bridge.—Wheatstone bridge when used for balancing inductances.

Inductance Coil.—A coil possessing inductance. (A coil can be wound so that it has a negligible inductance.)

Induction.—(See Electro-magnetic Induction and Electrostatic Induction.)

Inductive Capacity.—(See Capacity, Specific Inductive.)

Inductive Coupling.—Two circuits are said to be inductively coupled when a current flowing in one will induce an E.M.F. across the other with the help of its varying magnetic field.

Inductive Reactance.—The part of the impedance opposition due to the self-induction of the circuit. It is denoted as $2\pi fL$, where $\pi = 3{\cdot}1416$, f is the frequency in cycles per second, and L is the inductance in henries.

Inductive Resistance.—Resistance wire wound in the form of a coil so that apart from possessing resistance it also has inductance, and therefore offers the passage of high-frequency currents an opposition higher than that of ohmic resistance only.

Inductor Loud Speaker.—A moving iron type of loud speaker in which the armature is given a larger degree of freedom that compares favourably with that of a moving coil. It reproduces low-frequency notes better than other types of moving iron speakers.

Insulation.—Isolation of electrified bodies or conductors in which currents flow, from earth and one another. Insulating substances have molecules of such complex nature and the atoms within the molecules are so strongly bound together that the surface atoms of an insulating substance are unable to part with their " planetary " electrons (see *electron*), and thus are unable to produce either within them or on their surface what is known as the flow of electrical current. For this reason if two conductors are separated by an insulating substance and a voltage is applied across the conductors, the intervening insulation will stop the migration of electrons from one conductor to another; in other words, the migrating electrons will be unable to penetrate the domain of the surface atoms of the insulating substance.

Insulation Resistance.—If a voltage is applied across an insulating substance, and if this voltage is high enough, a comparatively weak current may flow through the insulation. On calculation it is found that the resistance of an insulating substance is of the order of several million ohms. The resistance of an insulating substance diminishes with the increase of temperature (it raises in the case of conductors).

Insulator.—A shaped piece of insulating substance used for mounting bare conductors so as to isolate them from earth. Insulators are made in all sorts of shapes out of porcelain, glass, ebonite, etc.

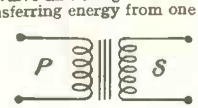
Inter-electrode Capacity.—Capacity between the valve electrodes. While this capacity can be neglected in ordinary reception, with short waves it becomes important, and is then equivalent to a number of small capacity condensers being introduced into the circuit.

Interference.—In reception of wireless signals of a given station—undesirable electrical disturbances due to other stations, to commercial electrical apparatus, or to atmospheric disturbances.

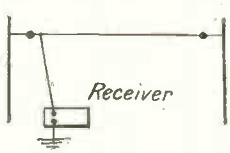
Internal Impedance of a Valve.—This is the ratio of a small change in anode voltage to the corresponding change in anode current, the grid volts remaining constant.

Intervalve Coupling.—An arrangement of components placed between the anode of one valve and the grid of the next valve for the purpose of transferring energy from one valve to another.

Intervalve Transformer. — A transformer used for coupling one valve to another. The primary winding is connected to the anode of the first valve and the secondary winding is connected to the grid of the next valve.



Inverted L Aerial. — An aerial wire which continues at one end as the leading-in wire to the receiver. The whole thing looks like an inverted letter L. This aerial possesses some slight directional properties.



Ionisation.—An atom which has lost or gained electrons, *i.e.*, become electrified, is called an ion. Ionisation is atomic electrification, either positive (electrons lost) or negative (electrons gained).

Isochronous.—Two alternating currents of the same frequency but out of phase (out of step) are said to be isochronous.

J

Jack.—A name given to an assembly of contact springs which are mounted on the " body " of the jack (a thick bent piece of metal with a circular opening to accommodate a plug). When a plug is pushed in between the springs some of them are forced apart and some are brought into contact, and thus a number of circuits which are connected between pairs of springs are broken and closed automatically.

Jamming.—Wiping out completely the signals that are being received by other interfering signals which are much louder. Morse signals from a close-lying station may thus completely wipe out broadcast reception.

Jar.—A naval unit of capacity equal to 1/900 of a microfarad.

Joule.—This is the practical unit of energy equivalent to one watt-second. One joule can also be defined as the amount of energy possessed by 1 ampere flowing for one second with an E.M.F. of 1 volt. One joule is equal to 10^7 ergs.

Joule, James Prescott.—Born 1818, died 1889. An English physicist who established the relation between heat and electricity. The practical unit of energy is named after him.

Joule's Law.—This law states : " The amount of heat generated in an electrical circuit is proportional to the square of the current, also proportional to the resistance of the circuit and the time during which the current flows." Thus, the amount of heat is proportional to I^2Rt.

Junction, Thermo-electrical.—(See Thermo-electricity.)

K

Kathode.—Another way of spelling cathode.

KC.—Abbreviated *kilocycles.*

KC/S.—Abbreviated *kilocycles per second.*

Keeper.—A piece of iron placed across the poles of a permanent magnet in order to keep the magnetic circuit closed while the magnet is not in use.

Kennelly-Heaviside Layer.—(See Heaviside Layer.)

Key.—A spring contact which keeps open till it is pressed down by hand. Used in telegraphy for transmitting morse signals (dots and dashes). It is also called *morse key* or *tapping key.*

Kilocycle.—One thousand cycles (time not specified).

Kilohertz.—One thousand cycles *per second.*

Kilovolt-ampere.—A thousand *volt-amperes* (which see).

Kilowatt.—The practical unit of electrical power. One kilowatt equals a thousand watts.

Kilowatt-hour.—One kilowatt developed for an hour. This is what is called the Board of Trade unit of electrical energy.

Kinetic Energy.—Energy possessed by a body in virtue of a force being applied to it. An example of a body possessing kinetic energy is that of a shell fired from a gun. The force applied to the shell is that due to the expanding gases inside the gun.

Kirchhof, Gustave Robert.—Born 1824, died 1887. A German physicist famous for his mathematical researches in the domain of electricity. He formulated the Kirchhof's laws.

Kirchhof's Law.—1st law : " When a number of currents meets at a point their algebraic sum is zero." (This means that there is no accumulation of electrons at that common point.) 2nd law : " In any closed circuit the algebraic sum of the products of current and resistance (*i.e.,* voltage drop) in each part of the circuit is equal to the electromotive force acting across the circuit as a whole."

Knife Switch.—A switch which has a pivoted flat blade for making contact with double spring contacts. Aerial-earth switches are of this type as a rule.

kVA.—Abbreviated *kilovolts-amperes.*

kW.—Abbreviation for *kilowatt.*

L

Lagging Current.—An electrical alternating current which is being retarted by the self-inductance of the circuit, and for this reason its changes occur after the E.M.F. changes have occurred. It is said to lag behind the E.M.F.

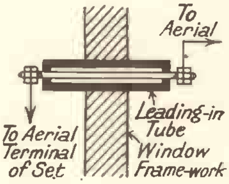
Laminated Core.—An iron core made of thin sheets of metal in order to prevent the formation of eddy currents (see) and the consequent heating of the core. Sometimes such a core is made up of a bunch of iron wires.

Laminations.—Iron or steel stampings used for building up electro-magnet cores.

Lead.—Another name for connecting wire. Hence the use of terms : *accumulator leads, battery leads, loud speaker leads,* etc.

Lead Accumulator.—An accumulator having both plates of lead, specially *formed* by electro-chemical processes.

Leading Current.—An alternating current, due to the discharge of a condenser and always being present in a circuit when capacity is present, which happens before the E.M.F. has been *again* applied to the condenser. It is therefore said to be leading the E.M.F.



Leading-in Tube. — An ebonite hollow tube containing a copper rod inside, the rod being supplied with a terminal at each end. A hole is drilled in the framework of the window through which the leading-in tube is inserted and the aerial down-lead is connected to the terminal outside the house and the receiver aerial terminal lead to the inside terminal.

Leak.—(See Grid Leak.)

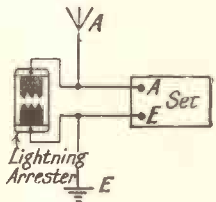
Leaky Grid Detection.—(See Cumulative Grid Rectification.)

Leclanché Cell.—This is a primary cell with a carbon positive electrode and a zinc negative electrode. The electrolyte is salammoniac plus a depolarising chemical agent. Used chiefly for electric bells.

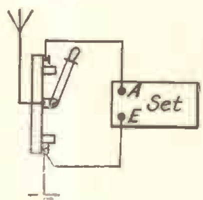
Lenz's Law.—" When a conductor moves with respect to a magnetic field the currents induced in the conductor are in such a direction that the reaction between them and the magnetic field opposes the motion of the conductor."

Leyden Jar.—An early form of a condenser consisting of a glass jar covered with tinfoil inside and outside. The two layers of tinfoil forming the two plates and the glass the dielectric.

L.F.—Abbreviated *low frequency.*



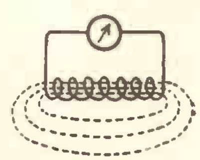
Lightning Arrester.—This is a component, one type of which consists of an exhausted glass tube enclosing two saw-edged carbon pieces, placed end on end and separated by a small gap. When connected across the aerial and earth terminals of the receiver (in parallel with the aerial and earth) it provides an easy discharge path to heavy surges of current induced by atmospheric charges or a near lightning discharge, and thus saves the receiver from being damaged.



Lightning Switch.—A single-pole double-throw switch of the knife-blade variety. The aerial is connected to the centre terminal (to the rocking blade). the receiver aerial terminal is connected to one of the contacts and the other end contact carries two wires, one direct to earth and the other to the receiver earth terminal. In this manner the aerial, when not in use, can be connected straight to earth.

Linear Amplification.—Amplification over the straight portion of the valve characteristic curve. This is achieved by adjusting the grid voltage so that the working value of the current falls upon that straight portion. Under these conditions a change in anode current is directly proportional to the change in grid volts and distortionless amplification is the result.

Lines of Force.—These are the lines along which magnetic and electric forces act in their respective fields. In the case of a magnetic field these lines of force can be made visible with the help of iron filings. The lines of force of an electric field can be similarly mapped out with the help of pivoted straws. Lines of force have no actual existence. but are merely imaginary lines along which electric and magnetic forces act.



Lines of Induction.—Another name for lines of force.

Linkages.—This is a term applied to lines of force of a magnetic field threading turns of wire. If one line of force passes through a turn of wire it is said to form one linkage. If five lines of force are threading two turns of the coil there are ten linkages formed. Similarly, two lines of force threading five turns will form ten linkages. Therefore linkages are the product of the number of lines of force and the number of turns they are threading. When the number of linkages is rapidly changing, induction takes place. This is another way of saying that lines of force are cutting the conductors of a coil.

Loading Coil.—The wavelength of an aerial is proportional to the product of inductance and capacity. If one is increased the wavelength to which the aerial can respond best (*i.e.*, to which it is tuned) will also increase. For this reason if we connect in series with the aerial a coil we shall increase the inductance of the aerial and therefore its wavelength. This is the reason why such a coil is called a loading coil.

Local Oscillations.—Oscillations produced within the receiver with a local oscillator.

Local Oscillator.—An oscillator valve incorporated within the circuit of a superheterodyne receiver for the purpose of producing local oscillations of E.M.F. to be combined with the received E.M.F. so that a resultant or beat E.M.F. can be formed.

Logarithmic Condenser.—A variable air condenser in which the angle of plate movement is proportional to the logarithm of the change in capacity. This is achieved by giving the vanes a special shape.

Logarithmic Decrement.—(See Decrement.)

Long Waves.—Waves having a wavelength above 3,000 metres (Hague definition).

Loose Coupling.—Two coils are said to be loosely coupled when they are some distance apart so that their mutual inductance is smaller than the product of their self-inductances.

Loud Speaker.—An electrical reproducing apparatus in which a cone diaphragm (modern types) is made to vibrate with the help of either a moving iron armature or a moving coil, both vibrating in a magnetic field.

Low Frequency.—Frequencies below 15,000 cycles per second.

Low-frequency Amplification.—Amplification of voltages applied to the grid of valves after the detector (rectifier) stage.

Low-frequency Amplifier.—Part of the receiving circuit between the detector valve and the loud speaker.

Low-frequency Transformer.—An iron-cored transformer used in the low-frequency circuits.

Low-pass Filter.—A filter circuit which is designed to pass all frequencies below a certain value.

Low Tension.—A term used to indicate the voltage of the filament battery as distinct from the much higher voltage of the anode or high-tension battery.

Low-tension Battery.—The battery connected across the filament of a valve or valves.

L.T.—Abbreviated *low tension*.

M

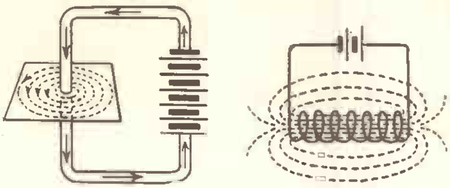
Magnetic Circuit.—This is a term used in connection with magnetism in analogy with the electrical circuit. In an electrical circuit we have an electro-motive force applied across the circuit, and this E.M.F. causes a current to flow against the resistance of the circuit. In the case of an electro-magnet which consists of a coil of wire mounted on an iron core, the core represents the magnetic circuit (magnetic path through which the magnetic lines of force spread). The ampere turns of the coil, *i.e.*, the product of the number of turns in the coil and the current in amperes flowing through it, produce the force that gives rise to the magnetic flux and which is thus called the magneto-motive force. The flux that is given rise by the M.M.F. is similar to the current flowing in a conductor. This flux spreads against the *reluctance* of the magnetic material. In the case of a coil without an iron core when the magnetic circuit is represented by the air surrounding the coil, the following relation holds good :—

$$\text{Flux} = \frac{\text{M.M.F.}}{\text{Reluctance}}.$$

But with magnetic materials this is no longer true, as reluctance varies with flux density.

Magnetic Damping.—A method of damping the movement of the pointer of a measuring instrument by attaching to the inner end of the pointer a metallic disc which has to move between the poles of a magnet. Eddy currents (which see) are induced in the disc and the magnetic field formed by those eddy currents is acted upon by the magnet's field so that the pointer is arrested in its vibrations and the instrument is made "dead beat."

Magnetic Effect of Electrical Currents.—When a current flows in a wire there is a magnetic field around the wire in the form of concentric circles. This can be proved by threading the wire through a sheet of paper and sprinkling the paper with iron filings. When the wire is wound into a coil the magnetic lines of force around the



wire add up into a resultant magnetic field which spreads round the coil.

Magnetic Field.—If a permanent bar magnet is covered by a piece of stiff and not too thick paper and the paper is sprinkled with iron filings, it is found that the iron filings arrange themselves always into the same pattern which occupies a considerable space around the magnet. The stronger the magnet the wider this pattern is spread. The lines forming this pattern are called *lines of force* and the pattern itself is referred to as the *magnetic field*. This magnetic field exists all round the magnet in all the three dimensions. A straight line drawn tangentially to a line of force indicates the direction of the magnetic force. A similar magnetic field will appear around a conductor or a coil carrying an electric current. (See *Magnetic effect of electrical currents* and *Molecular magnetism.*)

Magnetic Flux.—The total number of lines of force existing in a magnetic field around a magnet is called the *magnetic flux*. The number of lines of force per unit area taken at right angles to the lines of force is called the *flux density*. Flux density serves as a measure of the strength of a magnetic field.

Magnetic Force.—The magnetic force or the strength of the magnetic field at any point (also referred to as *field strength*) can be measured by the force exerted by the field upon a *unit magnetic pole* (which see) placed at that point.

Magnetic Induction.—When a permanent magnet is placed near a piece of iron the latter becomes magnetised at a distance (without actual contact), and this is called magnetic induction. Similarly if an iron core is placed within a coil of wire through which current is flowing, the magnetic field around the core will magnetise by induction the iron core, and the latter will produce a magnetic field of its own. For this reason the flux density (which see) within the core due to the two fields will be greater than the flux density inside the coil with the core removed (in air). The term *magnetic induction* is therefore also applied to the flux density within such a core, *i.e.*, within a magnetic circuit.

Magnetic Inductive Capacity.—The term capacity is misapplied here. (See Permeability.)

Magnetic Linkages.—(See Linkages.)

Magnetic Remanence (also called Remanent Magnetism).—An iron core within a coil carrying a current will become magnetised. When the current is switched off, and the magnetic field around the coil disappears, it is found that some of the magnetism remains within the iron. This is called magnetic remanence.

Magnetic Screen.—Lines of force of a magnetic field can pass easier through iron than air. For this reason, if a coil of wire carrying an electric current is surrounded completely by an iron cover, the magnetic field will be concentrated within the iron of the cover and will not go beyond (outside) it. Such an iron cover forms, therefore, a screen of the lines of force.

Magnetic Shunt.—A piece of iron placed in measuring instruments near the permanent magnet so as to draw off some of the flux into the iron from the air gap. Thus in analogy with the electric shunt the iron serves as a branch magnetic circuit, and hence the name shunt.

Magnetisation Curve (also called B/H curve, where B is flux density in a magnetic material and H is the flux density in air under the same conditions).—This is a curve showing the relation between magnetising force (another name for H) and the flux density.

Magnetising Force.—In a coil of wire carrying a current the flux density produced in air which is the measure of the magnetising force within the coil depends upon and is proportional to the number of ampere turns (which see).

Therefore : magnetising force $= \frac{4\pi \times IT}{10\,L}$, where I is the current and T is the number of turns, and L is the length of coil in centimetres. In other words, the magnetising force due to a coil is equal to $\frac{4\pi}{10} \times$ number of ampere turns *per centimetre* length of the coil. (Compare this formula with that of the M.M.F.)

Magneto-motive Force.—This is the sum of all the magnetising forces within the coil carrying a current. If per each centimetre of length the magnetising force equals $\frac{4\pi}{10} \times \frac{IT}{L}$ the sum of all the magnetising forces will be L times that, so that the M.M.F. $= \frac{4\pi}{10} \times \frac{IT \times L}{L}$ or $\frac{4\pi IT}{10}$. Hence the M.M.F. $= \frac{4\pi}{10} \times IT$.

The magneto-motive force is the force which causes the flux to come into existence and which forces it through the magnetic circuit.

Magnetophone.—A microphone built on the moving coil principle. The coil is flat and very light, so that it will vibrate under the influence of the sound waves emitted in front of the microphone. It is made to move in a magnetic field supplied by a permanent magnet or an electro-magnet, and thus has currents induced in it while in motion. The stronger the motion the stronger the current. Thus sound waves can be interpreted in the form of varying currents.

Magnetron.—A thermionic valve in which the flow of electrons is controlled by means of a magnetic field.

Magnification Factor.—(See Amplification Factor.)

Mains Unit.—A unit consisting of a smoothing circuit, and in the case of alternating currents also incorporating a step-down transformer and some form of rectifier which is added to a battery receiver in order to convert it for use with mains supply, from which anode voltage, filament voltage and grid voltage are obtained.

Manganin.—An alloy of copper and nickel.

Man-made Static.—Another name for interference caused by industrial electrical machines and appliances.

Mansbridge Condenser.—Small, fixed capacity, condenser giving a larger capacity for bulk as the plates are made in the form of a roll of tinfoil separated by paper dielectric.

Mass.—The number of molecules in a given volume. The unit for measurement of mass on the C.G.S. system is the gramme (which see).

Mast.—A wooden or steel latticed structure or pole used for supporting the aerial wire or wires.

Matched Impedance.—This term refers to matching the internal resistance of the output valve with the impedance of the loud speaker at middle frequencies of the acoustic range.

Maximum Value.—(See Amplitude.)

Maxwell.—An electro-magnetic unit for measuring magnetic flux. One *maxwell* equals one line of force.

Maxwell, James Clerk.—Born 1831, died 1897. A famous English physicist who predicted mathematically the existence of electro-magnetic waves. The unit of magnetic flux is named after him.

Mechanical Rectifier.—Another name for a commutator (which see). Also a vibrating reed which vibrates with the frequency of the current to be rectified and makes and breaks contact at the right moment so that it always picks up current in the same direction.

Medium Waves.—Waves having a wavelength lying between 3,000 and 200 metres. (The Hague definition.)

Megger.—A measuring instrument which gives a direct reading of high resistances in ohms.

Megohm.—One million ohms.

Mercury Arc Rectifier.—A rectifier must possess unidirectional conductivity. In a rectifier of this type mercury is vaporised from the negative electrode and an electric arc is formed. This arc possesses unidirectional conductivity.

Metal Rectifier.—One form of such a rectifier is a copper plate coated on one side with copper oxide in contact with a plate of lead. Such an arrangement possesses unidirectional conductivity and therefore rectifies alternating currents. It is claimed that a similar arrangement may be used for detection purposes in a receiver without a detector valve as a sort of a crystal detector.

Metallised Valve.—A screened-grid valve has to be screened with the help of metal shields from other circuits in order to avoid interference of high-frequency electric fields with other parts of the circuit. Such a shield or screen can be formed by spraying the glass of the valve with metal and thus eliminating other screens.

Metre-ampere.—A unit used in transmission for measuring the radiated power. This is a product of the effective height of the transmitting aerial in metres and the current in amperes.

Metre-bridge.—A Wheatstone bridge which has a variable resistance 1 metre long.

Mfd.—Abbreviated *microfarad*.

MHO (the word Ohm backwards).—This is a unit of conductivity which is the reciprocal of resistivity and also of conductance which is the reciprocal of resistance.

Microampere.—A millionth of an ampere.

Microfarad.—A millionth of a farad.

Microhenry.—A millionth of a henry.

Microhm.—A millionth of an ohm.

Microphone.—A device for interpreting sound waves in the form of varying electrical impulses so that there is a particular electrical impulse corresponding to every sound. This is done by varying either the resistance of the circuit (carbon microphone), or the inductance of the circuit (magnetophone microphone), or the capacity of the circuit (condenser microphone). Any of such variations of electrical constants of the circuit will produce varying currents. The microphone is connected to an amplifying circuit as the electrical impulses produced in it, whatever the form, are weak.

Microphone Amplifier.—A low-frequency amplifying circuit connected to a microphone.

Microphonic Valve.—(See Anti-Microphonic Valve.)

Micro-ray.—Electro-magnetic waves of wavelengths below 1 centimetre. Such waves can be dealt with, from the point of view of reflection and refraction, in a manner similar to an optical ray.

Milliammeter.—An ammeter (an instrument for measuring the strength of electrical currents) calibrated and therefore giving a reading in milliamperes.

Milliampere.—A thousandth of an ampere.

Millivolt.—A thousandth of a volt.

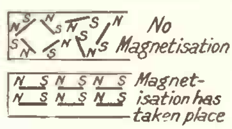
Millivoltmeter.—A voltmeter (an instrument for measuring E.M.F.) calibrated and giving a reading in millivolts.

M.M.F.—Abbreviated *magneto-motive force*.

Modulation.—Superimposing of microphonic variations of current on to the carrier current flowing in the transmitting aerial. One way of doing this is to vary the amplitude of the carrier wave.

Molecule.—A molecule is the smallest particle of any substance, be it a chemical element (a simple substance of which there are ninety-two and of which all other substances are made up), or a complex union of such elements, which still bears all the characteristics of the substance in question. Molecules of different substances differ in size. It is estimated that the diameter of an average molecule is 1/125,000,000 of an inch. Each molecule is made up of atoms (which see), and the reason why the size of molecules varies is that the molecule of each substance has a different number of atoms in it. A molecule of water has three atoms: two atoms of hydrogen and one atom of oxygen. Other molecules may have 2,000 atoms and more.

Molecular Magnetism, Theory of.—Magnetic induction (which see) is explained as being due to the fact that every molecule of a magnetic substance is a tiny magnet. Therefore, when a magnetising force comes into play, all molecule-magnets have to turn their north or south poles one way, *i.e.*, in orderly rows of molecules. In a non-magnetised piece of magnetic material these molecules point with their poles in any direction, so that there is no definite polarity. This is an old theory, but modern science tends rather to confirm it. When a current flows in a wire there is a magnetic field around this wire. An electrical current is merely an electrical charge in motion. Now, an electron is an electric charge. When it is in motion in its orbit it is equivalent to an electric current, and therefore there must be a magnetic field around each electronic orbit. With a number of electrons in motion there is a number of magnetic fields associated with the atom, and therefore every atom must possess a magnetic field around it. A molecule which consists of atoms must also have a magnetic field around it, due to the atomic magnetic fields. If the atoms are so disposed and move in such a manner that their magnetic fields add up, the molecule acquires a resultant field with definite polarity, as it is the case with molecules of iron, steel, nickel and cobalt. When the fields do not happen to add up, the molecule does not possess any appreciable magnetism, as is the case with non-magnetic materials. Generally speaking every molecule possesses some magnetism associated with it, and for this reason we divide all non-magnetic substances into paramagnetic materials (attracted by a magnetic pole) and diamagnetic substances (repelled by a magnetic pole).



Molecular Vibration.—All molecules are in a state of perpetual vibration, be the body solid, liquid, or in a gaseous state. The total energy possessed by the molecules of the body is what we call the *total amount of heat* in the body. The rate of molecular vibration determines the *temperature* of the body. The higher the temperature the more violent this vibration is. At absolute zero (which see) temperature, all molecular vibration should stop, and the molecules should be at rest. How this would affect the cohesive forces between the molecules remains to be seen, when the temperature of absolute zero is reached, experimentally. It is this violent molecular vibration of molecules in a solid body with certain temperatures that accounts for a similarly violent vibration of atoms and the throwing off of electrons into space, as in the case of a valve filament.

Momentum.—This is the product of mass and velocity of a body.

Morse Code.—A signalling code consisting of combinations of dots and dashes (one dash is equal in duration to three dots) separated by equal intervals of silence. Each combination represents some letter of the alphabet or some numeral.

Morse Inker.—An instrument which records automatically in ink morse code messages.

Morse Key.—A tapping key for sending out Morse signals.

Motor-boating.—These are low-frequency oscillations of the order of a few cycles per second set up in the low-frequency amplifier of a mains receiver employing a battery eliminator, owing to one anode circuit affecting another.

Motor-convertor.—(See Anode Converter.)

Motor-generator.—(See Anode Converter.)

Moving Coil Loud Speaker.—A light coil of wire is suspended to move freely within the magnetic field in the air gap of either an electro-magnet or a permanent magnet. A cone diaphragm is connected to the coil mechanically so that the coil and the cone diaphragm vibrate together. The output current of the receiver is made to pass through the coil with the result that there is a varying magnetic field formed around the coil. As the field varies and reacts upon the permanent magnetic field, the coil vibrates and causes the cone diaphragm to vibrate with it. Sound waves are thus produced by the diaphragm.

Moving Coil Measuring Instruments.—In measuring instruments the deflection of the pointer which is fixed to some form of a moving system must be proportional to the strength of current flowing through the instrument. As such flow of current is accompanied by a magnetic field, this magnetic field is made to react upon another magnetic field, and the repulsion or attraction between these two fields is responsible for the motion of the moving part of the instrument. There are two main types of such instruments. One type is the so-called *moving iron type* in which the current to be measured flows through a coil and a piece of iron is placed near this coil to be magnetised by induction. The iron is either "sucked in" or repelled, and its movement is greater the greater the current flowing. The other type (moving coil) consists of a permanent magnet providing a steady magnetic field and a light coil suspended within the air gap of this magnet. The coil is mounted upon an iron core. The current to be measured is passed through the coil and the magnetic field around the coil reacts upon the field of the permanent magnet, so that the coil moves. Whatever is the instrument, an ammeter or a voltmeter, we measure the current and the scale interprets it in amperes and volts respectively, as the relation between current and voltage with a constant resistance is given by Ohm's law.

Moving Coil Microphone.—(See Electro-dynamic Microphone.)

Moving Iron Loud Speakers.—In this type of loud speaker a piece of iron (armature) mechanically connected to a cone diaphragm, is placed within the magnetic field of an electro-magnet. The windings of the latter are connected to the output of a receiver and the currents flowing cause a varying magnetic field to come into existence. This varying magnetic field magnetises the iron armature by induction and causes it to vibrate as the field varies. The cone diaphragm vibrates with the armature.

Moving Iron Measuring Instruments.—(See Moving Coil Measuring Instruments.)

Multi-layer Coil.—(See Banked Winding.)

Multiple Tuner.—A tuner consisting of a number of tuning circuits, providing a selective arrangement.

Mutual Conductance (Valve).—This is the ratio of a small change in anode current to the corresponding small change in grid voltage, the anode voltage remaining constant. This ratio is usually stated in milliamperes per volt.

Mutual Inductance.—Two coils possess a mutual inductance of 1 henry if the current in one coil while changing at the rate of 1 ampere per second induces in the other coil an E.M.F. of 1 volt. Mutual inductance and the coefficient of mutual induction or the degree of mutual induction are the same thing.

Mutual Induction.—When two coils are placed near each other so that they are in each other's magnetic field, a change in current in one coil will induce an E.M.F. in the other coil, and *vice versâ*. This is called mutual induction.

N

Natural Frequency.—The frequency of free oscillations in an oscillatory circuit (a circuit possessing resistance, inductance and capacity) depends upon the inductance and the capacity of the circuit. It can be calculated approximately from the formula : $f = \frac{1}{2\pi\sqrt{LC}}$, where f is frequency in cycles per second, π is 3·1416, L is the inductance in henries, and C is the capacity in farads.

Natural Wavelength.—Since wavelength (which see) depends upon the product of inductance and capacity, an aerial is said to have a natural wavelength of its own in virtue of its inductance and capacity. This natural wavelength depends upon the dimensions and the height of the aerial. It means that there is a wavelength to which an aerial of given dimensions will respond best by offering the least possible opposition to currents induced by that wavelength.

Negative Charge.—A body is said to have a negative charge when its surface atoms have an excess of electrons over and above the normal quota of the atom. The charge is represented by the quantity of electricity contained in these surplus electrons. (See Electron.)

Negative Electrification.—Communication to the surface atoms of a body an excess of electrons.

Negative Ion.—An atom with an excess of electrons.

Negative Pole.—The negative electrode or terminal is spoken of sometimes as the negative pole. It is better to reserve the word pole to magnetism. A negative pole is the terminal of a source of E.M.F. having a surplus of electrons.

Negative Resistance.—As a rule, in accordance with Ohm's law, with a given resistance, as the voltage rises the current increases. In some apparatus such as the carbon arc, it happens that with the increase of current the voltage falls. This is due to the fact that the resistance changes in the arc. The resistance appears to behave in a way different to its ordinary behaviour, and for this reason it is spoken of as the negative resistance. The term is not a happy one.

Negatron.—A thermionic valve possessing four electrodes, two anodes, a grid, and a filament. The valve behaves as if it possesses negative resistance, hence the name.

Neon Lamp.—A special type of an electric lamp possessing two electrodes and containing an atmosphere of rarefied neon gas. When an E.M.F. is applied across the two electrodes a discharge takes place through the gas and a luminous glow appears around the negative electrode. This is chiefly used in television and the "talkies." It is also used as a visual indicator of discharge taking place across a condenser.

Neper.—A transmission unit of gain or loss of power. Neper $\frac{1}{2} \log_e \frac{\text{Power (input)}}{\text{Power (output)}}$. One neper equals 8·68 decibels.

Neutral Wire.—A wire at earth potential. (A term used in three-phase system of electrical distribution of power.)

Neutralising Coil.—A coil of wire used in connection with moving coil loud speakers to eliminate hum.

Neutralising Condenser.—A small capacity condenser used for balancing or neutralising the inter-electrode capacity of a thermionic valve.

Neutrodyne Receivers.—Before the advent of the screen grid valve H.F. amplification presented a difficult problem on account of the inter-electrode capacity of thermionic valves which tends to set up self-oscillations in the amplifying circuit and thus prevents good quality reception. Professor Hazeltine, of America, found a method by which this inter-electrode capacity could be neutralised. He connected small capacity condensers between the grid and the anode circuit.

Nodon Valve.—An electrolytic rectifier which has an aluminium cathode and a lead anode with the solution of ammonium phosphate as the electrolyte. Such a combination possesses unidirectional conductivity.

Non-conductor.—An insulator.

Non-inductive Condenser.—A fixed flat-plate condenser. (The Mansbridge spiral roll of tinfoil and paper condenser possesses a good deal of inductance.)

Non-inductive Resistance.—A resistance wound so that it has a negligible amount of inductance.

O

Oersted.—This is the unit of magnetic reluctance. A magnetic circuit is said to possess a reluctance of one oersted when a magneto-motive force of one gilbert will cause a flux of one maxwell.

Ohm.—The practical unit of resistance. *The international ohm* is the resistance of a column of pure mercury 106·3 centimetres long and having a cross-section of one square millimetre (its weight should be 14·4521 grammes) at a temperature of zero degrees Centigrade (32 degrees Fahrenheit). *The legal ohm* is the resistance at 16·4 degrees centigrade between the terminals of a "Standard Ohm" kept at the Board of Trade.

Ohm, Georg Simon.—Born 1787, died 1854. A German physicist who is the author of the Ohm's law. The unit of resistance is named after him.

Ohmic Drop.—(See Voltage Drop.)

Ohmic Resistance.—The resistance of a direct-current circuit. In an alternating-current circuit the opposition to the flow of the current is not only that due to ohmic resistance but also to the oppositions due to the self-inductance of the circuit and its capacity. In order to distinguish this opposition from the simple ohmic resistance it is called the *impedance* of the circuit.

Ohm's Law.—This law establishes the relation between the three electrical quantities involved in a direct-current circuit: the E.M.F. (voltage), the current, and the resistance. Ohm's law can be expressed in three ways: $I = \frac{E}{R}$; $R = \frac{E}{I}$ and $E = RI$, where I is current in amperes, E the E.M.F. in volts, and R resistance in ohms. (See also the Ohm's law formula for alternating currents in *resonance*).

Open Circuit.—A circuit which is not closed upon itself so that a current cannot flow all round it.

Open Core Transformer.—A transformer which has a core that does not represent a closed magnetic circuit, but part of the circuit is made up by an air gap.

Oscillation Constant.—This is the product $\sqrt{LC}$ from the formula given in *natural frequency* (which see).

Oscillation Transformer.—A high-frequency transformer, also called air-core transformer.

Oscillation Valve.—Any thermionic valve.

Oscillations.—Oscillation of electrons in an oscillatory circuit. These oscillations are merely electronic tides flowing to and fro in the circuit and maintained by some outside influence such as the passing electro-magnetic waves in the case of aerial oscillatory circuits or a valve in the case of amplifying circuits.

Oscillator.—An electrical circuit producing oscillations.

Oscillator Valve.—A thermionic valve in a transmitter or a superheterodyne receiver that is made to produce continuous oscillations.

Oscillatory Circuit (also referred to as the Oscillating Circuit).—This is a circuit possessing resistance, inductance and capacity, and the resistance is low enough to allow the current in the circuit to oscillate at the natural frequency of the circuit when an alternating E.M.F. is applied to it. Although it may sound ridiculous there are many amateurs who imagine that an oscillatory circuit will oscillate, *i.e.*, have an oscillating current flowing in it without any E.M.F. being applied to it at all. The reason for this is probably that they look upon the diagram of an aerial circuit, see in it an oscillatory circuit, and forget that induced oscillations are set up by the passing electro-magnetic wave.

Oscillatory Current.—An oscillating current flowing in the oscillatory circuit (which see).

Oscillograph.—(See Cathode Ray Oscillograph.)

Out of Phase.—A term applied to two or more electrical quantities such as alternating currents, E.M.F.'s or electro-magnetic waves, when they vary out of step. This means that we may have two alternating currents of which one is a maximum while the other is zero, and so on.

Output.—In electrical circuits the power delivered at the end of a series of components. In the case of a wireless receiver the output is obtained across the loud speaker terminals.

Output Choke.—A low-frequency choke connected in the anode circuit of the last valve and whose function it is to reject all high-frequency currents from the loud speaker circuit and thus to maintain the quality of reproduction.

Output Transformer.—A low-frequency transformer connected between the last valve and the loud speaker.

Output Valve.—The last valve of a receiver.

Overlap.—(See Back-lash.)

P

Pancake Coil.—(See Basket Coil and Slab Coil.)

Parallel Connection.—A number of components connected across two common wires. When a number of cells of equal E.M.F. are connected in parallel the resultant E.M.F. is that of a single cell. If the E.M.F.'s are unequal the resultant E.M.F. is that of the largest E.M.F. cell. When a number of resistances or inductances are connected in parallel the reciprocal of the resultant resistance or inductance is equal to the sum of the reciprocals of individual resistances or inductances $\left(\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} \text{ etc.}\right)$. When a number of condensers are connected in parallel the resultant capacity is the sum of individual capacities.

Parallel Feed.—A parallel branching off of an anode circuit, one branch being made up of a resistance or an inductance and the other branch of a fixed condenser. While the high-frequency pulsating current is able to produce electronic tides on both sides of the condenser, the direct component of the anode current is unable to do so, owing to its steady character, and, being stopped by the condenser, is forced to flow through the resistance or the inductance.

Parasites.—An alternative name for atmospherics.

P.D.—Abbreviated potential difference.

Peak Value.—The maximum value of an alternating quantity.

Peanut Valve.—An early type of dull emitter valve.

Pentode.—A five-electrode valve consisting of a filament, three grids: next to the filament is the control grid; next to it is the screening grid, and the last grid is the collector grid which is connected to the filament inside the valve and is thus earthed; and the anode. This valve is the output valve of any receiver and is never used with more than one stage of L.F. amplification as it is easily overloaded. It gives interesting results when used as a detector.

Pentode Transformer.—An L.F. transformer specially designed for use with a pentode valve.

Percentage Coupling.—The coefficient of coupling expressed as a percentage.

Perikon Detector.—A crystal detector consisting of two crystals: zincite and bornite.

Period.—The time taken for one complete cycle to take place.

Periodicity.—Another name for frequency.

Permanent Magnet.—A steel, steel-nickel or steel-cobalt magnet which will retain its magnetism indefinitely unless subjected to heat treatment or violent mechanical shocks. Such permanent magnets are used in measuring instruments head-telephones, loud speakers, etc.

Permeability.—A term used in connection with the magnetic circuit. Not all materials pass with the same ease the lines of force of a magnetic field, *i.e.*, magnetic flux. Not all materials are equally well permeated by this flux. Hence the term permeability of materials. Permeability of different materials is measured by the ratio of flux density in the material and the flux density due to the same M.M.F. in air. The permeability of air and all non-magnetic materials is taken as unity. The permeability of various magnetic materials varies considerably and also depends upon the flux density. The latter is obvious, as however good the permeability of a material may be, lines of force will have a difficulty to force their way through an already crowded area (two magnetic lines of force cannot exist simultaneously in the same place).

Permeance.—The reciprocal of magnetic reluctance.

Permittivity.—(See Capacity, Specific Inductive.)

Phone.—Abbreviation for telephone.

Photo-electric Cell.—(See Cell, Photo-electric.)

Pick-up.—(See Gramophone Pick-up.)

Plain Aerial.—An aerial to which the receiver is connected directly without any loose coupled or intermediary circuits. Flat tuning is the result.

Plate.—Another name for the anode of a valve.

Plate Battery.—High-tension battery, anode battery.

Plate Circuit.—Anode circuit.

Plate Current.—Anode current.

Plate Impedance.—The internal impedance of a valve.

Plate Potential.—Anode potential.

Plate Voltage.—Anode voltage.

Polarisation.—Deposition of hydrogen on the positive plate of a primary cell which lowers the voltage of the cell. A depolarising chemical substance has to be used in order to get rid of this hydrogen.

Polarised Electro-magnet.—This is an electro-magnet, the iron cores (there are usually two cores and two coils) of which are clamped to a permanent magnet so that the cores are magnetised all the time, each pole piece having its own polarity. This arrangement is used chiefly in telephone ear-pieces.

Polarised Relay.—A relay circuit incorporating an electro-magnet with a polarised core.

Polarity, Magnet.—Each magnet has two poles situated close to the ends. One pole is called the north pole and the opposite pole is called the south pole. Like poles repel each other, and unlike poles attract each other.

Pole.—(See Polarity, Magnet; Negative Pole, Positive Pole.)

Polyphase.—An alternating-current circuit carrying a number of currents all out of phase (out of step).

Positive Charge.—The quantity of electricity represented by the unbalanced protons in the atoms of a body. Unbalanced protons mean that each proton has lost its balancing electron in the atom, and, since the quantity of electricity in a proton is equal to that in an electron, a positive charge is also a quantity of electricity contained in the *missing* electrons.

Positive Electrification.—A deficit of electrons in the surface atoms of a body, *i.e.*, a predominance of protons.

Positive Electrode.—(See Positive Pole.)

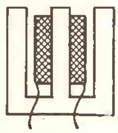
Positive Electron.—A term used *wrongly* instead of the word *proton*. This term comes from America. There is no such thing as a positive electron. An electron is a negative particle of electricity. A proton is a positive particle of electricity (see both).

Positive Ion.—An atom carrying a positive charge.

Positive Pole.—A positive terminal of a cell. The word pole is used wrongly here, and should be confined to magnetism in order to avoid confusion.

Post Office Box (also called Post Office Bridge).—A compact form of Wheatstone bridge for comparing resistance values.

Pot Magnet.—An electro-magnet, the core of which is made in the form of a pot. Chiefly used in moving coil loud speakers.



Potential. — This is the degree of electrification. An atom with a surplus of electrons has a greater potential than a neutral atom. Similarly, a neutral atom has a greater potential than an atom with a deficit of electrons. Electrons will pass from a body with a higher potential to a body with a lower potential. This is the only condition of electron migration from one conductor to another. Therefore, when a body has a larger number of electrons in its surface atoms as compared with another body made of the same material, it has a larger potential. Two bodies carrying similar and equal charges, but of different size, will have unequal potentials. The larger body with the same, say, negative charge, will have a smaller number of excess electrons per atom than the smaller body. The smaller body will therefore have a larger potential. The electric potential of a point is measured by the work done in ergs in bringing a unit electric charge from infinity to the point.

Potential Difference (or difference of potential).—This is the difference in the degree of electrification between two bodies. It can be said that the difference of potential between two bodies of the same material is the difference in the number of electrons in excess or in deficit, *per atom*. If electrons are to migrate from the surface of one body to the surface of another body, or to pass from atom to atom within a conductor, there must be a difference of potential between the bodies or the two ends of the conductor. Difference of potential between two points is measured by the work done in ergs in carrying a unit electric charge from one point to the other. The presence of a difference of potential between two points means that electrical energy can be converted into some other form of energy.

Potential Divider.—A high resistance used in low-frequency amplifying circuits which acts as a potentiometer and provides the grid of a valve with a variable potential. The potential is simply tapped off from point to point of the resistance.

Potential Drop.—(See Voltage Drop.)

Potential Gradient.—In a circuit across the ends of which there is a difference of potential, we have at one end the maximum negative potential and at the other end the maximum positive potential. In going from point to point of the circuit and starting with the negative end, we find that the negative potential gradually diminishes, at some point of the circuit becomes zero and its place is taken, as we go further along, by a gradually increasing positive potential. This means that as we start at the negative end and proceed from atom to atom we find that at the negative end there is the maximum surplus of electrons. This surplus gradually decreases in each atom as we go along the circuit till we reach an atom which is neutral. After that we discover atoms with a gradually increasing deficit of electrons till it becomes a maximum in the atoms at the positive end of the circuit. This is called potential gradient.

Potential Operated Device.—(See Voltage Operated Device.)

Potentiometer.—A bare wire resistance connected across some source of E.M.F., say a battery, and which has a sliding contact moving along its surface. Owing to the potential gradient existing in the resistance, the sliding contact can establish any difference of potential we like, within the given limits of the battery, between one end of the resistance and itself.

Poundal.—A unit of force on the foot-pound-second (F.P.S.) system of units. One poundal is approximately 1/32 pounds weight.

Power.—This is the rate of doing work. Electrical power is measured by the product of amperes and volts in a direct-current circuit and by the product of amperes, volts and the power factor (which see) in alternating-current circuits. The unit for measuring electrical power is the watt (1 watt equals 1 ampere multiplied by 1 volt; in a circuit in which a current of 2 amperes is flowing at a pressure of 10 volts, the power developed is 20 watts), 1,000 watts is called 1 kilowatt; 746 watts are equal to 1 horse-power.

Power Amplifier.—An amplifier incorporating the so-called power valves which are designed to deal with comparatively large power without distorting the signals.

Power Component.—In an alternating-current circuit the total current flowing can be divided into two component currents of which one is called the idle component (from the power point of view) as its energy is being devoted to such things as magnetisation, etc. The other component is called working or wattfull component, *i.e.*, the component which actually does the work for which the circuit is intended.

Power Factor.—In alternating-current circuits, owing to the presence of an idle component (see power component), the actual power developed is not the product of amperes and volts, but something less. Thus if we compare the actual power with the expected power we shall find that the actual power differs from the expected power by some quantity which is less than unity. This fraction is called the power factor, as the product of amperes and volts has to be multiplied by it in order to arrive at the true power.

Power Grid Detection.—A method of rectification employed chiefly with indirectly heated A.C. mains valves. The grid leak and the condenser have somewhat smaller values than in the case of ordinary cumulative grid rectification and the anode voltage is much higher. This gives a practically distortionless reproduction, as far as rectification is concerned.

Power Valve.—(See Power Amplifier.)

Pressure.—Another name for tension, voltage or E.M.F.

Primary.—Abbreviated primary winding or primary circuit, *i.e.*, the circuit to which an E.M.F. is applied in the first instance.

Primary Battery.—(See Battery, Primary.)

Primary Cell.—A source of E.M.F. consisting of two electrodes immersed in a chemical solution. Such a battery cannot be recharged electrically and is renewed by replacement of electrodes and the electrolyte.

Primary Circuit.—An electrical circuit influencing another circuit coupled to it. This is the circuit in which an E.M.F. is applied or induced in the first place.

Primary Winding.—The primary coil of a transformer.

Proton (please see first *electron*).—The proton is a particle of positive electricity, having the same quantity of electricity as the electron. It is smaller than the electron, but 1,884 times heavier. Practically the whole mass of the atom is represented by its protons. The radius of the proton is 10^{-16} centimetres. The mass of a proton is $1{\cdot}659 \times 10^{-24}$ grammes. All the protons in an atom are concentrated in its nucleus. In a neutral atom which has as many electrons as there are protons, each proton is balanced by its own electron. When an atom loses some of its electrons, an equal number of protons becomes unbalanced, so that there is in the atom an excess of positive electricity over the negative electricity. This is called a positive charge.

Pulsating Current.—A current which varies in amplitude throughout the cycle but never reverses its direction. This is the current that flows in the anode circuit of a valve. Engineers called this current the alternating component of the anode current because an alternating current superimposed upon a direct current can be resolved into a pulsating current. The name, "alternating component," used in conjunction with a unidirectional device such as the valve, is highly misleading.

Push-pull Method of Valve Coupling.—A method of valve coupling used both for amplification and rectification purposes. The valves are connected in parallel so that their filaments are fed from a common source. Their grids are connected across a common circuit, and so are the anodes. Such method of amplification or rectification is claimed to give the best results from the point of quality of reception. (See also Quiescent Push-pull.)

Pyrometer.—An instrument for measuring high temperatures based on the principle that resistance of a metallic conductor varies with the variation of temperature.

Q

Quantity of Electricity.—The smallest quantity of electricity obtainable in nature is that contained in an electron (or a proton), viz., $4\cdot774 \times 10^{-10}$ electro-static units. The practical unit of quantity of electricity is the coulomb (which see).

Quartz Crystal.—(See Crystal Control.)

Quiescent Aerial.—An aerial in which no carrier current is flowing when there is no modulation taking place. In other words, the carrier current ceases to flow as soon as the microphone diaphragm ceases to vibrate.

Quiescent Push-pull.—(Abbreviated as Q.P.P.) An old American method of low-frequency amplification by using two pentode valves in parallel. Such an arrangement gives a much larger output to battery sets, but the quality of reproduction is uncertain. To put it briefly: you connect the valves, get a large output, and hope for the best.

R

Radian.—A circle is divided into 360 degrees. A radian is an angle equal to 57·5 degrees, and is obtained by measuring on the circumference of a circle an arc equal in length to the radius and joining the ends of this arc by straight lines to the centre of the circle. In a circle there are 2π radians.

Radiating Circuit.—An aerial circuit in which a current flows and causes the emission of electro-magnetic waves into space.

Radiation.—Emission of electro-magnetic waves.

Radiation Coefficient.—(See Radiation Resistance.)

Radiation Efficiency.—This is the ratio of the radiated power in a radiating circuit to the power put into it. By multiplying this ratio by 100 we obtain the percentage efficiency.

Radiation Resistance.—If we divide the power radiated by an aerial by the square of the current flowing in it, we shall obtain the radiation resistance.

Radio Beacon.—A directional transmitting land station sending out automatic signals for the benefit of shipping and aircraft for direction finding purposes, *i.e.*, finding one's bearings.

Radio Frequency.—An American term for high frequency.

Radio-frequency Amplifier.—High-frequency amplifier.

Radio-frequency Choke.—High-frequency choke.

Radio-frequency Resistance.—High-frequency resistance which is somewhat higher than the ordinary resistance with direct current, for the same circuit.

Radio-frequency Transformer.—High-frequency transformer.

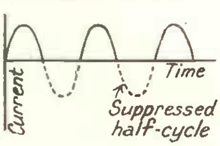
Radio-Gramophone.—A combination of a wireless receiver with an electrically driven gramophone motor and an electrical pick-up for reproduction of gramophone records.

Ratio of Transformation.—The ratio of primary turns to the secondary turns in a transformer.

Reactance.—This is the opposition offered to the flow of alternating current in a circuit by the inductance (inductive reactance) or capacity (capacitative reactance) of the circuit.

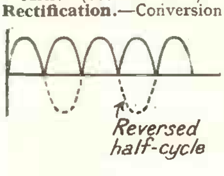
Reaction.—An output circuit influencing the E.M.F. of the input circuit. In wireless receivers the name reaction implies the "feeding" back of electrical oscillations from the anode circuit of the detector valve into the primary aerial circuit, the secondary aerial circuit or the anode circuit of one of the H.F. valves. Such reaction can be carried out either by inductive or capacity coupling. Reaction can be controlled by varying the coupling between inductively coupled coils or by varying the capacity of a variable condenser coupling the detector anode circuit to the circuit that is being influenced.

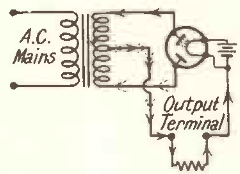
Reaction Coil.—A coil in the anode circuit of a detector valve coupled to either the aerial circuit or the anode circuit of an H.F. valve.



Reaction Condenser. — A variable condenser controlling the amount of reaction between two circuits. (See Reaction.)

Rectification.—Conversion of alternating current into unidirectional current. There are two methods of doing this. The first method is called half-wave rectification. In this case one half cycle is wiped out and the rectified current is represented by unidirectional varying pulses with equal periods of zero current. The second method is called full-wave rectification, and here the current is flowing throughout the cycle, only during one half cycle the current is reversed with the help of a tapped winding so that we have a pulse in the same direction each half cycle. The result of rectification is thus a unidirectional pulsating current, and this pulsating current is smoothed out into a steady current with the help of chokes and condensers.





Rectified Current. — An alternating current converted into direct current with the help of a rectifying device. (See Rectification.)

Rectifier.—A device capable of converting alternating current into unidirectional current. Such devices are some of the mineral crystals, thermionic valves, electrolytic and dry rectifiers, etc.

Rectifying Detector.—A unidirectional device, such as a valve or a crystal, included in the wireless receiving circuit.

Rectifying Valve.—Any valve is a rectifier. A two-electrode valve consisting of an anode and a filament is used for half-wave rectification. A three-electrode valve consisting of *two anodes* and a filament is used for full-wave rectification. A three-electrode valve consisting of a filament, a grid and anode will also act as a rectifier, and is used as a detector for this reason.

Reflection.—This term is used in connection with electro-magnetic waves and means that a wave on reaching either the Heaviside layer (in the case of long waves) or the Appleton layer (in the case of short waves) will be turned back to earth.

Reflex Circuit.—A circuit arranged so that a single valve gives both high-frequency and low-frequency amplification. This method is more or less obsolete.

Regeneration.—Another term for reaction (which see).

Regenerative Circuit.—A circuit employing reaction.

Reinartz Circuit.—A short-wave receiving circuit using capacity reaction.

Rejector Circuit.—A tuning circuit consisting of a condenser and a coil in parallel. When tuned to a given wavelength it will offer the currents induced by this wavelength a much greater opposition than that offered to currents induced by any other wavelength. In other words, it will respond to all waves except that to which it is tuned. For this reason it is used in wave traps. When such a circuit is used as a secondary aerial circuit it ceases to behave as a true rejector circuit on account of the method of connection.

Relay.—This is a device which will operate a circuit connected to it with a very small amount of energy applied to its own circuit. An electrical means of doing a large amount of work with a small expenditure of energy on the relay circuit. A thermionic valve acts as a relay as with a change of a small potential on the grid large changes in anode current are effected.

Relay Exchange.—A central station containing a wireless receiver which operates a large number of loud speakers in private residences with the help of telephone lines.

Reluctance.—A term used in connection with the magnetic circuit. This is the opposition offered by a magnetic material to the passage of magnetic flux through it. In air, the reluctance is the ratio of the M.M.F. to the magnetic flux.

Reluctivity.—The reciprocal of permeability (which see).

Remanence (Remannet Magnetism).—This is the property of an iron magnetic circuit of conserving part of the magnetic flux (residual magnetism) after the magnetising force is removed.

Remote Control.—A relay control of a wireless receiver from a distance.

Residual Magnetism.—(See Remanence.)

Resistance.—An electric current is the flow of electrons from atom to atom of a conductor. This being the case, it is clear that the local "planetary" electrons resident in the atoms which are being invaded will do their best to repel the invading electrons. In this manner the migrating electrons which constitute the electric current will experience a considerable amount of opposition. Since the atoms of every substance have a different number of "planetary" electrons, the opposition to the flow of electric current will vary with each substance. This is proved experimentally by measuring the resistance per unit volume (cubic inch or cubic centimetre) of each substance. Such resistance per unit volume expressed in microhms is called the *resistivity* of the material or its *specific resistance.* The resistance of a conductor depends in the first place upon the resistivity of the material, upon its length (the longer the conductor the greater the resistance), and upon its cross-sectional area (the smaller the cross-sectional area the greater the resistance). Mathematically this can be expressed as $R = \rho\frac{L}{A}$, where R is the resistance in ohms we are seeking, ρ is the resistivity *in ohms* per cubic inch, L is the length of the conductor in inches, and A is the cross-sectional area of the conductor in square inches. Under the same conditions the resistance offered to the passage of alternating currents, especially of high frequency, is somewhat greater than that offered to the passage of direct current, as the migrating electrons in rushing to and fro in the circuit encounter resistance both ways many times a second.

Resistance-capacity Coupling.—A method of coupling valves in the low-frequency amplifying circuit (this method is unsatisfactory in high-frequency amplifying circuits). A high resistance of the order of 50,000 ohms is inserted in the anode circuit of the amplifying valve between the anode and the H.T. battery. From the anode of the same valve a connection is made through a fixed condenser to the grid of the next valve. In series with this condenser is also inserted a grid leak (which also has a high resistance) which is connected to the negative side of the filament. The anode resistance develops a high voltage drop when the anode current flows through it, and this voltage drop, *i.e.*, difference of potential across the resistance, is passed on automatically to the grid circuit of the next valve. The condenser between the anode and the grid serves the purpose of isolating the grid from the H.T. battery, as otherwise a current would flow from the negative terminal of the H.T. battery, *viâ* the grid leak, *viâ* the anode resistance, and so back to the positive terminal of the H.T. battery. The grid leak serves for the purpose of timed electron leakage from the grid where an accumulation of electrons takes place. Owing to the absence of iron, this method of connection gives by far the best quality, although the volume is somewhat smaller than with other methods.

Resistivity.—(See Resistance.)

Resistor.—This is a fixed resistance which is added to a circuit to increase its resistance or is inserted between the negative terminal of the H.T. battery and the L.T. battery for the purpose of utilising the voltage drop across it for biassing the grid, which is connected to one end of the resistor. (See Automatic Grid Bias.)

Resonance.—Two electrical circuits are said to be in resonance when they are both tuned to the same wave-length, *i.e.*, in both, currents of the same frequency are flowing. Again, when an alternating E.M.F. is applied to a circuit having a frequency equal to the natural frequency of the circuit a state of resonance ensues. In this case the inductive reactance is equal to the capacitative reactance which, being equal and opposite, in effect wipe each other out, so that the only opposition present in the circuit is that of the pure ohmic resistance, and therefore a maximum current is flowing. Mathematically: in an alternating current circuit the current

$$I = \frac{E}{\sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}}$$

If $2\pi fL = \frac{1}{2\pi fC}$, then the expression inside the brackets is zero, and we are left with $I = \frac{E}{\sqrt{R^2}}$ or $I = \frac{E}{R}$, which is the ordinary direct current circuit formula. Thus for resonance $2\pi fL$ must be equal to $\frac{1}{2\pi fC}$.

Resonance Curve.—A curve showing the relation between the current and the frequency of a circuit with a constant inductance and capacity, across which voltages at varying frequencies are applied. The curve thus obtained looks like a peak. The sharper this peak the more selective the circuit is.

Resonating Circuit.—(See Oscillatory Circuit.)

Response Curve.—This is a curve showing the relation between the input and the output of an electrical instrument at different frequencies.

Retentivity.—The property of a magnetic material to retain magnetism after demagnetisation.

Retroaction.—(See Reaction.)

Retroactive Circuit.—(See Regenerative Circuit.)

R.F.—Abbreviated radio frequency.

Rheostat.—A variable resistance which is used for controlling the strength of current flowing in the circuit.

R.M.S.—Abbreviated for root mean square value of alternating current.

Root Mean Square Value.—A term applied to alternating quantities. An alternating current which varies in magnitude from instant to instant has an average effect equal to some direct current which will produce, for instance, the same heat in the circuit. In order to assess this effective value of alternating current as closely as possible, what is done is to take *the squares* of a number of instantaneous values of current throughout the cycle, find their mean (average) value, and take the square root out of that in order to reduce the whole thing to the power one. Hence the name.

Rotary Convertor.—(See Anode Convertor.)

S

Saturation (Magnetic).—Two lines of force of a magnetic field cannot occupy the same space, just as two solid bodies cannot occupy the same space. For this reason, when a magneto-motive force drives a flux through a magnetic circuit, a time will arrive when, however we increase this M.M.F., no further flux will be able to penetrate the magnetic circuit; in other words, the magnetic flux density will not increase any more. When this happens it is said that a state of magnetic saturation exists.

Saturation Current (in a Valve).—The current flowing from the filament to the anode of a valve increases with the increase of positive grid voltage, with the increase of anode voltage and with the increase, within permissible limits, of the filament current. But the filament possessing a limited number of surface atoms has a limited capacity for parting with electrons at any given time. A state of affairs may thus be reached that however we increase the anode voltage, and the grid voltage, the valve will continue to pass the same number of electrons as before, *i.e.*, its maximum number. This is called the saturation current of a valve.

Saturation Curve.—(See B/H Curve.)

Scanning Disc.—A disc, used in television, carrying a spiral of holes with or without lenses which is used for breaking up the transmitted picture into a series of narrow strips with the help of the scanning light.

Scanning Frequency.—The frequency with which a picture is scanned in television.

S.C.C.—Abbreviation for single cotton covered.

Screened Aerial.—An aerial with a counterpoise instead of earth.

Screen-grid Valve.—A four-electrode thermionic valve which has a filament, two grids and an anode. The grid next to the filament is the control grid equivalent to the grid of a three-electrode valve, and the grid next to the anode is the screening grid. The latter is given about half the positive potential applied to the anode. In this way there is a double pull upon the filament electrons. They, therefore, arrive at the anode with such a speed and force that they knock out from the surface atoms of the anode other electrons (secondary emission), and these secondary electrons, instead of affecting the control grid and thus distorting the received signals, land on the screening grid. This valve is used in high-frequency amplifying circuits of a wireless receiver and replaces entirely the old method of Hazeltine connections (with the use of neutralising condensers).

Screening.—In a wireless receiver, especially with the use of a screen-grid valve, high-frequency electric fields are developed which would influence low-frequency components and thus introduce distortion, unless they are prevented from doing so. For this reason the high-frequency circuits are screened, *i.e.*, completely enclosed within metal pots or partitions so that if any interaction takes place the H.F. electric fields waste their energy upon the surface atoms of the screens instead of L.F. components. It is for this reason that screen-grid valves are metallised on the outer surface.

Secondary Battery.—A battery of accumulator cells.

Secondary Cell.—(See Accumulator.)

Secondary Electrons (Secondary Emission).—(See Screen-grid Valve.)

Secondary Winding.—The output winding of a transformer in which an E.M.F. is induced from the primary winding.

Selectivity.—A term used in connection with a wireless receiver in order to indicate its ability of separating the different broadcasting stations. The most selective method of reception is the superheterodyne method.

Selenium Cell.—(See Cell, Selenium.)

Self-bias.—(See Automatic Grid Bias.)

Self-capacity.—A capacity is represented by two metal conductors separated by an insulating substance (dielectric). Two turns of close-lying insulated wire in a coil are two conductors separated by an insulating substance and must therefore possess capacity between them. For this reason, a coil as a whole possesses a certain amount of capacity distributed throughout its length, and this is called the self-capacity of the coil. This distributed capacity is equivalent to a concentrated capacity as represented by a condenser of an appropriate value placed in parallel with the coil.

Self-inductance.—Another name of the coefficient of self-induction.

Self-induction.—When an alternating current is flowing through a coil of wire it produces an alternating magnetic field around the coil, and the lines of force of this magnetic field, while moving in space with the growth and diminution in the intensity of the alternating current, will cut the conductors of the coil and will induce in them an E.M.F. additional to the applied E.M.F. This self-induced E.M.F. is called *the back E.M.F.* as it always opposes the action of the applied E.M.F. Since self-induction always opposes the applied E.M.F., it will prevent the current from growing or decaying too quickly. When the current begins to grow the back E.M.F. sends out local electrons in the opposite direction and thus reduces the main current. When the main current begins to diminish the back E.M.F. sends electrons in the same direction as the main current, and thus swells it for a time. This means that self-induction regulates the flow of the current in the circuit and forces it to change gradually instead of taking sudden jumps in value.

Self-oscillations.—(See Oscillations.)

Series Condenser.—A condenser connected in series with the aerial leading-in wire in order to drop the total capacity of the aerial circuit. Such condensers are, as a rule, fixed in capacity although variable condensers can be used with great advantage for this purpose.

Series Connection.—Electrical connection of components end to end. In the case of a series connection of cells, the resultant E.M.F. is equal to the sum of the individual E.M.F.'s. When resistances or inductances are connected in series, the resultant resistance or inductance of the combination is the sum of individual resistances or inductances. When condensers are connected in series, the reciprocal of the resultant capacity is equal to the sum of the reciprocals of individual capacities. Thus three condensers of three microfarads each, joined in series, will give a resultant capacity of 1 microfarad, which is a third of the capacity of one condenser (compare this with parallel connections).

Series-parallel Switch.—This is a double-pole double-throw switch which enables an automatic change-over from series to parallel connections.

Service Area (of a broadcasting station) is the area around the station in which satisfactory reception is possible.

S.G.—Abbreviation for screened grid.

Sharp Tuning.—The tuning of a receiver is said to be sharp when a very small change in the movement of the tuning condenser produces a definite separation of two wavelengths. In other words, one wavelength does not cover a large number of degrees on the tuning dial.

Shock Excitation.—Production of oscillations in an oscillatory circuit by a sudden electrical discharge.

Short Circuit.—An accidental crossing of two conductors, carrying a current, by a third conductor which shortens the route the current has to take and thus leaves part of the circuit inactive. Since the shortened route means less resistance to the flow of the current, the latter increases in value, and may cause serious damage either to the source of the applied E.M.F. or to any component it may have to pass.

Shortening Condenser.—(See Series Condenser.)

Short Waves.—Waves having a wavelength below 50 metres. (Hague definition.)

Shunt.—A slab of metal of very low resistance placed in parallel with the coil of an ammeter so that only a portion of the total current flows through the ammeter coil. Such shunts are used in ranges of different resistances.

S.I.C.—Abbreviated specific inductive capacity.

Side Bands.—A modulated carrier wave is a composite wave of waves of several frequencies, so that some of these frequencies are higher than the frequency of the carrier wave and some are lower. These frequencies above and below the carrier frequency are called side bands.

Silica Valve.—A transmitting valve which has a bulb of silica instead of glass in order to resist high temperatures.

Skin Effect.—Direct currents are flowing uniformly throughout the cross-section of the conductor. Alternating currents tend to flow only in the upper layers of atoms in the conductors, nearer to the "skin" of the conductor, and this is called the skin effect. The result of this is an increase in the resistance of the conductor, as compared with that in the case of direct current.

Skip Distance.—Owing to the reflection of waves from the upper ionised layers there are places where the wave is skipping over the earth's surface so that it cannot be received in that locality. This effect is especially noticeable in short-wave work, when the skip distances are of the order of a few thousand miles.

Slab Coil.—A coil which has a greater radial depth than the axial length. Its self-capacity is rather high, and therefore the coil is not satisfactory from the wireless reception point of view.

S.L.F.—Abbreviated straight line frequency.

Smoothing Circuit.—This is a combination of chokes and condensers for smoothing out the ripples of a rectified alternating current. Unless this is done, the receiver supplied with unsmoothed rectified current will develop a hum.

Solenoid.—A long cylindrical coil of wire.

Solid Back Microphone.—A special type of carbon microphone having two carbon discs, of which one is attached to the diaphragm and the other to the solid back of the microphone with carbon granules in between.

Space Charge.—This is a cloud of electrons between the filament and the anode in a two-electrode valve (there is no grid to regulate the traffic). These electrons in space on their way to the anode interfere with each other by repulsion and reduce the current through the valve. The grid has eliminated this trouble to a very great extent.

Space Current.—(See Anode Current.)

Space Ray.—(See Indirect Ray.)

Specific Inductive Capacity.—(See Capacity, Specific Inductive.)

Specific Resistance.—(See Resistance.)

Spreader.—A short length of wood or a wooden hoop used for separating elevated aerial wires.

Square Law Condenser.—A variable condenser with air dielectric in which the movement of the rotating vanes is directly proportional to the change in wavelength. Since the change in wavelength is proportional to the *square root* of change in capacity, the condenser has been given the name of a square law condenser.

S.S.C.—Abbreviated single silk covered.

Static Characteristic (of a Valve).—(See Characteristic Curve.)

Static Charge.—A stationary electric charge.

Statics.—(See Atmospherics.)

Steel Tape Recorder.—(See Blattnerphone.)

Stopping Condenser.—(See Blocking Condenser.)

Step-down Transformer.—A transformer the secondary winding of which has fewer turns than the primary, so that the induced secondary voltage is lower than the applied primary voltage.

Step-up Transformer.—A transformer the secondary winding of which has more turns than the primary winding, and therefore the secondary induced voltage is higher than the primary applied voltage.

Storage Battery.—(See Accumulator.)

Storage Cell.—(See Accumulator.)

Straight-line Frequency Condenser.—This is a variable condenser with air dielectric in which the movement of the rotating vanes is such that a given angle of rotation gives the same change in frequency, whatever the position of the moving vanes.

Strays.—(See Atmospherics.)

Sulphating.—When an accumulator has been left uncharged for a long period its lead plates become covered with a white deposit of lead sulphate and the accumulator is said to be sulphated. Such an accumulator has to be specially treated before it is ready for action again.

Superheterodyne Reception.—(See Beat Reception.)

Super-power Valve.—Output valves capable of handling comparatively high powers of the order of 500 milliwatts.

Supersonic Frequency.—A frequency just above the audible range.

Surface Leakage.—A leakage of current over an insulating substance owing to moisture or dirt. Thus, there may be a leakage across aerial insulators or across the surface of an H.T. battery, etc.

Surge.—A heavy rush of electrical current. May be due to an accumulated static electrical charge on the aerial, on account of atmospheric electricity.

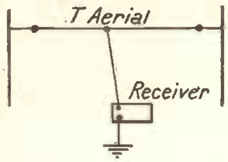
S.W.G.—Abbreviated standard wire gauge.

Synchronism.—A term used in connection with two machines running at the same speed and in step. This term also applies to two alternating currents varying in step (in phase).

Syntony.—Two circuits are said to be in syntony when their natural frequencies are equal. (See Natural Frequency.)

T

T Aerial.—An aerial which has its down lead connected in the centre so that the whole forms the letter T.



Tapping. — A connection made at some point between the ends of an inductance or a resistance.

Telephone.—An assembly of appliances which enables speech to be transmitted between two distant points connected by two wires. Conversationally this name applies to the telephone receiver (or head-telephones) which consists of a polarised electro-magnet (which see) and a soft iron diaphragm. As the current through the windings of the electro-magnet changes the diaphragm vibrates and produces sound waves.

Telephone Condenser.—A small-capacity condenser connected across the telephone windings to bypass high-frequency currents or audible frequency currents which produce high-pitched notes.

Telephone Jack.—(See Jack.)

Telephone Transformer.—A step-down transformer connected between the output of a receiver and the telephones or loud speaker. In this manner the anode current of the last valve does not flow through the windings of the reproducing instrument. With head-telephones this is a much safer arrangement.

Telephone Transmitter.—A transmitter capable of transmitting music and speech either by land line or wireless.

Television.—A term which means seeing by wireless. Just as sound waves can be interpreted in the form of varying electrical currents, so light variations can be interpreted as currents and fed to the aerial for transmission purposes. In this manner moving objects can be made visible at great distances and sounds transmitted simultaneously in the ordinary way. Two separate transmitters are employed working on different wavelengths and two receiving aerials and two sets are necessary at the receiving end, one for sound and the other for vision. Television transmissions are now part of the B.B.C. programmes, and rapid advance is being made in the new art. (See also Cell, Photo-electric; Cell, Selenium.) The system of television employed at the moment is the Baird system.

Temperature Coefficient.—The resistance of metallic conductors rises with the increase of temperature, and the resistance of insulating substances diminishes with the increase of temperature. The temperature coefficient is the increase in resistance of a metallic conductor for every degree centigrade rise in temperature.

Tension.—A term meaning E.M.F., voltage or difference of potential. The battery connected to the anode of a valve is for this reason called the high-tension battery (it has a voltage of the order of a hundred volts), and the filament battery is called a low-tension battery which has a voltage of 2, 4 or 6 volts.

Terminal.—A device with an adjustable threaded cup or nut which carries the end of a wire or wires and permits a quick interchange of connections.

Tetrode.—Another name for a four-electrode valve (seldom used).

Thermionic Amplifier.—A valve amplifier.

Thermionic Current.—The flow of electrons inside the valve from the filament to the anode.

Thermionic Detector.—A valve detector.

Thermionic Emission.—Electron emission from a valve filament.

Thermionic Oscillator.—A valve oscillator which generates continuous oscillations in conjunction with an appropriate circuit.

Thermionic Valve.—This is an exhausted glass bulb containing a number of electrodes. The usual types of such valves are the two-electrode, three-electrode, four-electrode and five-electrode valve. Each valve contains a heated filament which emits electrons from its surface atoms. The electrons are attracted by a positively charged anode and their flow from the filament to the anode is controlled by the grid or a number of grids. The input side of a valve is represented by the grid circuit to which varying potentials are applied either by the aerial circuit or the output side of a preceding valve. The output side of a valve is represented by the anode circuit. For this reason, the valve is said to be a voltage-operated device. The inner electrode is the filament which is surrounded by a wire or mesh grid or grids. The latter are surrounded by a cylindrical thin metal anode. Each electrode is separately supported and the supports are insulated from each other. Connections are made to each electrode and are brought outside the sealed valve to its "legs," which are merely spring contacts fitting into the sockets of a valve holder.

Thermo-electricity.—If one end of a junction of two different metals is heated while the other end remains cold, an E.M.F. is generated across the two junctions, and a current flows round the two metals. This effect is used in practice in some forms of measuring instruments.

Thoriated Filament.—A valve filament treated with thorium which is rich in planetary electrons. Such a filament will provide satisfactory emission at a lower temperature than a metallic filament which is not treated in this way.

Three-coil Holder.—A coil holder which accommodates three different coils of which one is usually stationary and the other two can be moved in respect of the stationary coil.

Three-electrode Valve.—A thermionic valve possessing a filament, a grid and an anode.

Tight Coupling.—A term applied to two coupled circuits the coils of which are brought close together so as to obtain the maximum of mutual induction.

Time Signal.—The broadcasting of the Greenwich time by wireless.

Topping-up.—Adding distilled water to an accumulator in order to bring the concentrated acid on account of evaporation to its proper specific gravity.

Toroidal Coil.—A coil wound in the shape of a closed ring.

Transformation Ratio.—(See Ratio of Transformation.)

Transformers.—A transformer is an electrical appliance for altering the intensity of the available E.M.F. There are two types of transformers: the iron-cored transformer and the air-cored transformer. In wireless work the former type is used in low-frequency circuits, and the latter type is used in high-frequency circuits. A transformer has two windings which consist sometimes of sectional coils joined in series. One winding, which is called the primary winding or simply *the primary*, has the available *varying* E.M.F. applied to it. This varying E.M.F. produces in the primary a varying current which in its turn produces a varying magnetic field. The lines of force of this varying magnetic field cut the conductors of the other winding at right angles and induce an E.M.F. in them. For this reason the other winding is called the secondary winding. If the secondary winding is closed upon itself a varying current will flow in it. The transformer has a very high efficiency, so that, neglecting the small losses of energy in the transformer it is near enough to say that the *input to the primary* (the product of voltage and current, *i.e.*, watts) *is equal to the output from the secondary.* Also *the volts per turn of the primary are equal to the volts per turn in the secondary.* In this manner we can have more turns in the secondary than in the primary, and thus have a larger E.M.F. developed across the secondary. On the other hand, we can have a larger number of turns in the primary than in the secondary and have a smaller voltage induced in the secondary. Since the outputs are equal, it means that in the primary we may have a small voltage and a large current with a corresponding large voltage and small current in the secondary. (See also Air-core Transformer, Intervalve Transformer, Step-up Transformer and Step-down Transformer.)

Transmission Unit.—This is one decibel, a unit of loss or gain of energy.

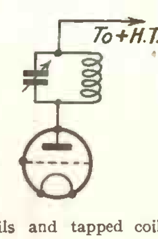
Transmitter.—A name which covers all the apparatus connected to the transmitting aerial for the purpose of radiating electro-magnetic waves in signalling or broadcasting.

Trickle Charger.—An apparatus incorporating some rectifying device and used for slow home charging of accumulators when the latter are not in use.

Trimming Condenser (Trimmer).—A small-capacity condenser added to a gang of variable condensers for the purpose of final adjustment of capacity so as to compensate for the added capacity of metallic parts holding the condensers together.

Triode.—Another name for a three-electrode valve.

True Power.—A term used for the power developed in an alternating circuit which is the product of volts, amperes, and the power factor (which see).



Tuned Anode.—This term refers to a rejector circuit (a coil and a variable condenser in parallel) connected in the anode circuit of a valve. This method of intervalve coupling is used in the pre-detector, *i.e.*, high-frequency stages.

Tuned Circuit.—An electrical circuit the inductance or the capacity of which can be varied with the help of different coils or a variable condenser respectively. (Slider coils and tapped coils or variometers may be used for the purpose of varying the inductance of the circuit.)

Tuned Plate Circuit.—Another name for tuned anode circuit.

Tuner.—The aerial circuit or circuits of a receiving set, the inductance and/or capacity of which can be varied.

Tuning.—Adjusting the capacity or inductance of an electrical circuit so as to produce in it a desired frequency of induced oscillating current.

Tuning Coil.—The coil incorporated in a tuning circuit.

Tuning Condenser.—A variable condenser incorporated in a tuning circuit.

Tuning Constant.—(See Oscillation Constant.)

Tuning Inductance.—Another name for tuning coil.

Tuning Note.—A low-frequency note sent out by a transmitting station before the beginning of a broadcast so that the receivers can be tuned in.

Two-electrode Valve.—A valve consisting of a filament and an anode.

U

Ultra-short Waves.—Wireless waves below 10 metres (Hague definition).

Umbrella Aerial.—A form of an elevated aerial in which the wires are arranged around a pole like the ribs of an umbrella.

Undamped Oscillations (or Waves).—This means continuous oscillations (waves).

Unidirectional Conductor.—A conductor such as a crystal or a valve which will allow a current in a circuit to flow in one direction only, say from right to left, but not back again.

Unidirectional Current.—A direct current, a current flowing in one direction only.

Unilateral Conductivity.—The conductivity possessed by unidirectional conductors.

Unit Electric Charge.—This is an electric charge which, placed at a distance of 1 centimetre from an equal charge, will exert upon it a force of 1 dyne.

Unit Magnetic Pole.—This is a magnetic pole which at a distance of 1 centimetre from an equal pole will exert upon it a force of 1 dyne.

Unloaded Aerial.—An aerial to which neither a loading coil nor a series condenser have been added.

Untuned Aerial (also called Aperiodic Aerial).—An aerial that cannot be tuned, as it has nothing variable. Used chiefly in short-wave work.

Untuned Circuit.—A circuit that cannot be tuned, *i.e.*, a circuit the electrical constants of which cannot be varied.

V

Vacuum.—Space free of all matter, be it solid, liquid or gas (space filled with ether (which see)).

Vacuum Tube.—(See Thermionic Valve.) An American term.

Vacuum Valve.—(See Thermionic Valve.)

Valve.—(See Thermionic Valve.)

Valve Adapter.—A valve holder that can be plugged in into a different type of a valve holder

Valve Amplifier.—An electrical circuit consisting of a valve or a number of coupled valves either in cascade or in parallel.

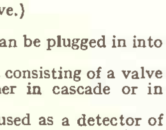
Valve Detector.—A thermionic valve used as a detector of wireless signals. Its function is to separate the high-frequency component of anode current from the low-frequency component.

Valve Oscillator.—(See Thermionic Oscillator.)

Valve Receiver.—A wireless receiver employing thermionic valves for amplification and detection purposes.

Valve Voltmeter.—A valve can be used for measuring small alternating voltages. The voltage to be measured is applied to the grid of a three-electrode valve, and a milliameter in the anode circuit, specially calibrated, gives a reading in volts.

Variable Condenser.—A condenser consisting of two sets or three sets of vanes of which one set or two sets can be moved in respect to one set which is fixed in position. The change in the overlap area of the fixed vanes and the moving vanes causes a change of capacity which is thus varied. (See also Logarithmic, Straight-line Frequency and Square Law Condensers.)



Variable Inductance.—This is either a slider contact solenoid coil, a tapped solenoid coil or a variometer. In a slider coil the inductance is varied by tapping off with the help of a sliding contact a varying number of turns. In a tapped coil each tapping represents a certain number of turns and is connected to studs of a multi-way switch. In the case of a variometer, two coils are used connected in series and one coil is made to rotate within the other. The relative position of the two coils determines the addition or subtraction of their magnetic fields, and thus the inductance is varied.

Variable-mu Valve.—This is a screen-grid valve which is so designed and so biassed that with a strong signal the grid receives automatically a large negative bias which gives a small mutual conductance (the ratio of a small change in the value of the anode current to the corresponding small change in the value of the grid voltage, the anode voltage and the filament emission remaining constant) resulting in small amplification and, therefore, in less volume. With a weak signal the negative bias is automatically reduced and the amplification increased, and with it the volume. The use of such a valve in a modern receiver will result in an even reception of all stations, weak and strong, within practicable limits.

Variocoupler.—A form of variometer.

Variometer.—(See Variable Inductance.)

Vector.—A straight line drawn to scale to represent some force and the direction and sense of the line being the same as those of the force in question. (By direction we mean the angle the line makes with the horizontal, and by sense the way the arrow head indicates which way the force acts.) A vector is therefore a line oriented in three respects: magnitude, direction and sense.

Velocity.—This is the distance travelled by a body in unit time.

Velocity of Light.—Light is an electro-magnetic wave. All electro-magnetic waves travel in space with the same velocity of 300,000,000 metres per second or 186,000 miles per second.

Vernier Condenser.—A small-capacity variable condenser capable of very fine adjustment.

Very Short Waves.—Waves below 10 metres (above 30,000 kcs./sec.).

Volt.—The practical unit for measuring E.M.F.'s.

The *international volt* is $\frac{1}{1\cdot0183}$ of the E.M.F. of the Weston cadmium cell at 20° Centigrade. It is also defined as the E.M.F. which will send a current of 1 ampere through a resistance of 1 ohm. (See Ampere and Ohm.) The *legal volt* is one-hundredth of the potential difference which produces a certain deflection on a standard electrostatic voltmeter kept at the Board of Trade.

Volta, Alessandro.—Born 1745, died 1827. A famous Italian physicist who invented the voltaic pile, *i.e.*, a method of generating E.M.F.'s by contact of two different metals with a saline solution. The volt is named after him.

Volt-Amperes.—The product of volts and amperes used for calculations in alternating-current circuits, as distinct from power which is the product of volts, amperes and the power factor (which see).

Voltage Amplification.—Magnification of the intensity of the E.M.F. from stage to stage in a valve amplifier. The E.M.F. induced by the passing electro-magnetic wave across the aerial circuit is very minute, as only a tiny fraction of total energy radiated by the transmitting aerial reaches the receiving aerial. This E.M.F. is applied across the grid circuit of the first valve. The small variations of potential across the grid produce comparatively large changes in the value of the anode current. The anode current flowing through a suitable component produces variations of potential across the anode circuit. The voltage thus developed across the anode circuit is much larger than that applied in the first place across the grid. In this manner the voltage has been magnified, and it is a mirror-like reproduction of the variations of the applied grid voltage. The voltage across the anode of the first valve is applied to the grid of the second valve, and so from stage to stage voltages are magnified till the desired output is obtained.

Voltage Amplification Factor (or Constant).—(See Amplification Factor.)

Voltage Drop.—If we measure the voltage at the terminals of a power station and measure the voltage supplied at the terminals of a house a few miles away, we shall find that the house voltage is smaller than the voltage at the power station. The reason for this is that the line connecting the station to the house (two wires running between the two points) has resistance and the difference in the two voltages is equal to the resistance of the two wires multiplied by the strength of current flowing in them. Thus: station voltage − voltage dropped in the line = house voltage. It is for this reason that we talk about a voltage drop. Generally speaking, a voltage drop occurs in every conductor and is numerically equal to the resistance of that conductor multiplied by the current flowing through it

(E = RI). Since the voltage drop is proportional to the resistance, we shall find that in the case of a long coil of wire wound as a *resistance* the voltage drop will vary from point to point and for this reason such a resistance can be used as a potentiometer or voltage divider.

Voltmeter.—Generally speaking, a voltmeter is an ammeter with a resistance in series. For this reason we have moving-iron and moving-coil voltmeters. A voltmeter is a measuring instrument for measuring voltage and its scale is calibrated in volts. What it actually measures is the voltage drop across its resistance.

Volume Control.—A potentiometer or a variable resistance connected in the circuit of a receiver for reducing the loudness of sound emanating from the loud speaker.

W

Wander Plug.—A split spring contact at the end of a wire for tapping off voltages from the sockets of an H.T. battery. A red cap indicates the positive contact and a black cap indicates the negative contact.

Water-cooled Valve.—In large transmitting valves which handle a large power, so much heat is generated at the anode on account of electron bombardment that it is necessary to cool the anode. This is usually done with the help of water.

Watt.—A practical unit of electrical power. One watt is equal to 1 ampere multiplied by 1 volt.

Watt-hour.—This is the power expended in a circuit by 1 watt in one hour ; 1,000 watts expended for one hour form a kilowatt hour, which is the B.O.T. unit.

Wattmeter.—A measuring instrument for measuring electrical power, and is a combination of an ammeter and a voltmeter.

Wave Distortion.—(See Distortion.)

Wave Form.—This is the outline of a curve showing the variation of current, E.M.F., or an electro-magnetic wave.

Wavelength.—All electro-magnetic waves travel in space with the same velocity of 300,000,000 metres per second. Thus, every radiation has to cover the same distance in one second. This can be done by a single wave occurring in a second, or, say, a million of waves occurring in a second. Thus the length of each wave will depend upon the frequency with which these particular waves occur each second. The higher the frequency, *i.e.*, the more waves occur in one second the shorter each wave will be. (See Frequency.)

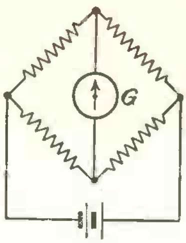
Wavemeter.—An instrument for measuring wavelengths.

Wave Trap.—A rejector circuit or a combination of a rejector and an acceptor circuit used in the aerial circuit for elimination of interference.

Waves (Wireless).—(See Electro-magnetic Waves ; see also Wireless Waves, Classification of.)

Weber.—A C.G.S. unit of magnetic pole strength.

Wheatstone Bridge.—This is a combination of three known resistances to which a fourth unknown resistance is added.



The known resistances are variable. When the circuit is adjusted so that the voltage drop in each pair of resistances is equal and opposite, two points of the circuit, between which a galvanometer is connected, acquire the same potential. Since there is no difference of potential between these two points, the galvanometer has no current flowing through it, and its pointer fails to deflect. This serves as a sign that the resistances are balanced. The value of the unknown resistance is then calculated from the values of the known resistances between which a simple relation exists. A similar method is applied for finding the values of unknown capacities and inductances.

Wipe-out.—A term given in connection with too large a negative potential induced by too strong a signal in the grid circuit of a detector valve. The large negative potential on the grid stops the valve from operating and the receiver stops to perform. The signals are thus wiped out. This is now prevented by the use of the variable-mu valve (which see).

Wipe-out Area.—The immediate locality of a powerful transmitting station the signals from which wipe out all other signals.

Wireless Waves, Classification of.—Long waves, above 3,000 metres (below 100 kilocycles per second). Medium waves, between 3,000 and 200 metres (between 100 and 1,500 kcs./sec.). Intermediate waves, between 200 and 50 metres (between 1,500 and 6,000 kcs./sec.). Short waves, between 50 and 10 metres (between 6,000 and 30,000 kcs./sec.). Very short waves, below 10 metres (above 30,000 kcs./sec.).

X

X's.—(See Atmospherics.)

X-Stopper.—A circuit adopted for minimising interference from atmospherics. There is no really effective device for this purpose.

Z

Zero Potential.—Earth potential.

Zincite.—A mineral consisting of zinc oxide. It is blood red in colour. Zincite can be used for detecting purposes either with a cat's whisker or in connection with telurium or chalcopyrite.

CLASSIFIED KEY

THEORY

INSTALLATION, MAINTENANCE AND SERVICING

CONSTRUCTIONAL

DESIGN

EXPERIMENTAL

MATHEMATICS

GENERAL

MISCELLANEOUS

INDEX

Vol. I., pages 1–392. Vol. II., pages 393–776. Vol. III., pages 777–1160. Vol. IV., pages 1161–1544.

Printed in Great Britain for the Proprietors, GEORGE NEWNES LTD., 8-11 Southampton Street, Strand, W.C.2, by THE WHITEFRIARS PRESS LTD., London and Tonbridge. Sole Agents—Australasia: GORDON & GOTCH (Australasia) LTD. South Africa: CENTRAL NEWS AGENCY LTD.

ERRATA FOR VOLS. I.—IV.

(All have been implemented in this pdf.)

Page 41, col. 1. Valves should be 1, P.M. 202 ; 2, P.M.I.H.F. ; 1, P.M.I.H.L. ; 1, P.M.I.L.F. (all Mullard).

„ 55, col. 1. From line 3 delete sentence " If an . . . accurate."

„ 92, Fig. 17. H.T.+ at bottom right-hand corner should be H.T.—.

„ 312 and 315. Transpose captions of Figs. 6 and 11.

„ 317. In Figs. 13 and 14 the word " circuit " should read " current."

„ 439, col. 1. 1 5,000 ohm volume control should be 1 50,000 ohm volume control.

„ 440, col. 1. 0·05 mfd. condenser and 1,000 ohm shunt resistance type Tubular are separate components.

„ 957, col. 2. 3rd line from foot " ·0005 mfd. " should be " ·00005 mfd."

„ 1225, Fig. 8. There should be a 1 mfd. fixed condenser between L.T.— and H.T.+ 2.

„ 1242, col. 2, line 3. For " multiplied " read " divided " Lines 5 and 12. For " ML^3 " read " ML^{-3}."

„ 1249, col. 1. 3 lines from foot. For " watt per second " read " watt-second."

„ 1279, Fig. 6. There should be a short length of flex with safety S.G. anode connection attached to terminal P of the Second Intermediate-Frequency Transformer.

„ 1400, col. 2, line 38. For " an ordinary . . . the same case " read " a straightforward transformer, the tone control being obtained by a principle which is the multitone patent, and is a matter of transformer winding pure and simple."