

THE RADIO
AMATEUR'S HANDBOOK

A. FREDERICK COLLINS

THE RADIO AMATEUR'S HANDBOOK

*A Complete, Authentic and Informative
Work on Radio Telegraphy
and Telephony*

BY

A. FREDERICK COLLINS

Author of "Wireless Telegraphy" 1905

SEVENTH EDITION

REVISED BY

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INTRODUCTION BY

DONALD McNICOL

Editor of *Radio Engineering*

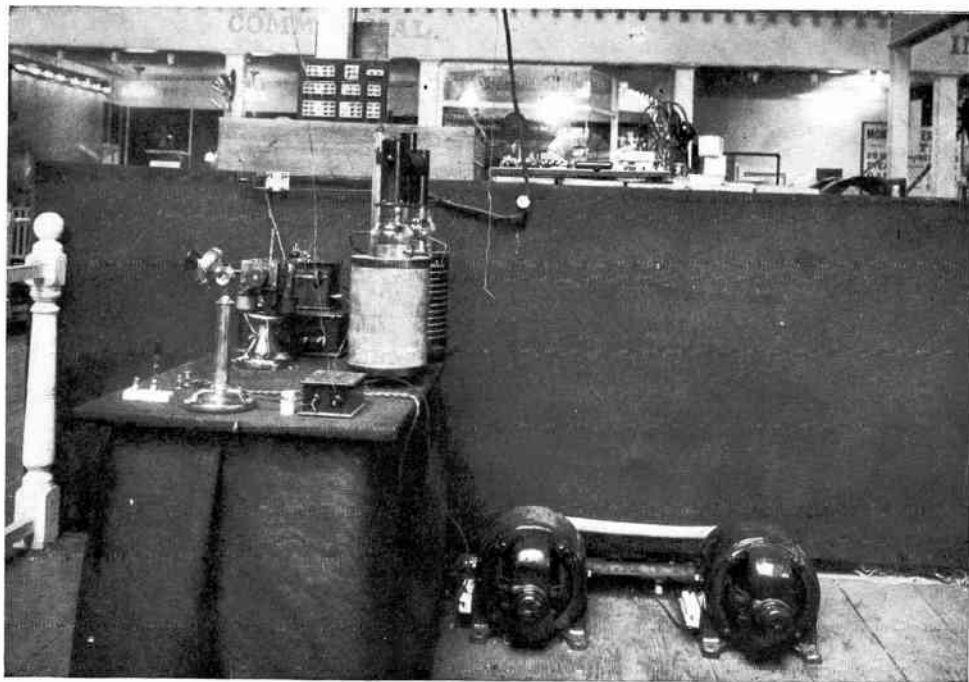
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PREFACE TO THE SIXTH EDITION

IN the two years that have elapsed since the last revision of this Handbook, the radio industry has progressed certainly within itself and, furthermore, it has lent a helping hand to other industries.

The progress within the industry itself has been chiefly along the lines of more perfect apparatus with attendant improved reception. The screen-grid vacuum tube has made possible the reduction of the number of tubes used in a receiver, and the reproduction has been better than ever before due to the new power tubes. The further developments of alternating-current tubes and power-supply units have made practical a receiver that will operate from any source of 110-volt alternating current, thus eliminating all batteries. The electrodynamic loud speaker has undergone striking improvements, with the result that today it is possible to hear music which compares favorably with that played or sung in the studio.

Since the talking-machine has borrowed the audio-frequency amplifier and loud speaker, it seems quite needless to mention what radio has done for the field of talking motion pictures. Constant improvement in film plays with sound has been, and is being made, due to these aids from radio.

But it is with the amateur and his viewpoint of the subject that we are chiefly interested. Short-

wave "work" has arrived and is here to stay. Nightly, amateurs are in communication across oceans, and the power they are using is only a fraction of what was necessary before to reach stations a few hundreds of miles distant, instead of thousands.

In the revising of the Handbook the editor of this edition has endeavored to retain the elementary data, and still give some of the latest developments with which the up-to-date amateur should be familiar.

Two receivers primarily designed for use on the lower wavelengths have been included, as well as two short-wave transmitters, one of these latter being for both code and telephone. The constructional details for a power amplifier using 245-type tubes in the push-pull output stage have been given, for with a pick-up and this amplifier it is a simple matter to obtain wonderful results from your old talking-machine. For those interested only in broadcast reception, an a-c. receiver has been described which is conceded to be a leader for all-round performance.

The receivers and transmitters mentioned above have been selected because they may be obtained in kit form. To get the maximum results from apparatus and circuits is beyond the skill of many amateurs, if they buy miscellaneous parts and connect them in an unintelligent fashion. It seems far more practical to purchase parts especially designed for a circuit, and assemble and connect them according to the instructions of engineers who have studied the circuit from every angle.

As the industry progresses, naturally new practices have appeared from time to time. A chapter on new tubes has been added, as well as chapters on filters and power-supply units, power detectors, and the progress that radio has made in other fields. A new vacuum-tube characteristic chart has been added in the Appendix, as well as other new data.

Within the next few years the amateur will have the pleasure of witnessing great progress in that field which should be foremost in the mind of every true experimenter—radiovision, or, as it is more commonly known, television. There is in this phase of radio a vast opportunity for the experimenter to do something that will afford him the greatest pleasure, for even now it is possible to see as well as hear by radio. Still there is much to do—many “bugs” to be removed from the apparatus, and who knows but that some amateur, young in the game, may make a name for himself by some improvement small but yet important. To that end a chapter on radiovision has been included, although the data given will doubtless soon be obsolete; yet with the apparatus described, the amateur can get a start in this extremely interesting field. And it is safe to say, if once he does start he will find a subject that will fascinate him to the Nth degree. At the present time several high-powered stations are broadcasting radiovision and radiomovies on regular schedules, so he will easily find something to see.

That the radio industry is still progressing most rapidly is evidenced by the fact that since the manuscript was set in type, there has been another step

forward made in the apparatus for the transmission and reception of radiovision signals. Dr. V. Zworykin of the Westinghouse Electric and Manufacturing Company, announced the completion of experiments on the use of a cathode-ray tube, instead of the neon lamp, scanning disk and all the other cumbersome apparatus heretofore used. Of course, Zworykin's apparatus is still in the laboratory stage, but it is an important advance.

The editor of this edition wishes to express his appreciation to M. L. Muhleman and A. P. Peck for the advice and aid they have so generously given him in the revision of the Handbook.

G. C. B. R.

New York

April 1, 1930

PREFACE TO THE SEVENTH EDITION

THE present edition of the Handbook has been brought up to date by the addition of chapters on the photoelectric cell, the latest developments in vacuum tubes and television apparatus, talking motion pictures and ultra short-wave transmission and reception.

Of greatest interest to the amateur is this matter of the quasi-optical frequency waveband, for it is in this portion of the spectrum that future possibilities lie dormant. The efforts of some of our foremost scientists are directed towards solving the problems presented by apparatus for wavelengths under five meters and, if history is to repeat itself, the amateur will do his part in this work.

G. C. B. R.

February, 1933

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INTRODUCTION

THE BACKGROUND OF MODERN RADIO

IN the popular mind, "radio" came into being about the year 1895, when Guglielmo Marconi, a young Italian experimenter, demonstrated with elementary circuits and accessories that it was possible to transmit intelligible signals through space without wire connection between sending and receiving stations.

And, so far as the practical worker in radio is concerned, that may be far enough back to go for a beginning. It has been experience, however, that those who take up seriously the study of radio in time develop a curiosity to learn about the various small and the large steps forward made by scientists and physicists who by many years preceded Marconi in discovering the principles of electricity and magnetism which made radio possible.

It is important first for the student to master the practical details of radio transmitters and receivers so that he may have the technical knowledge necessary to serve in a responsible and profitable position—to earn a living from radio. To the industrious student this book will be found to be an excellent textbook on the subject. A thorough understanding of its contents should constitute a groundwork for the study of advanced radio engineering.

Introduction

After a student has become familiar with the circuits, equipment, and systems in use at the present time, to set up radio transmitting and receiving units, and he finds time to satisfy his curiosity about the remote beginnings of the science, he will learn many interesting truths.

He will learn that it was not until about the year 1800 that Volta's primary chemical battery was available to experimenters; that it was in the year 1819 that Oersted, in Denmark, discovered that the electric current flowing in a wire produced magnetic effects similar to those produced by a natural, lodestone magnet. He will learn that between the years 1819 and 1840, a bewildering array of important discoveries were made by Ampere, in France; William Sturgeon, in England; Michael Faraday, in England; Joseph Henry, in America; and by others,—which discoveries gave to experimenters the electromagnet, the electric condenser, and the induction coil, with much knowledge of electric circuits and their arrangement.

Following the year 1840, after the advent of Morse's electric telegraph, many experimenters were at work on various electrical developments, out of which came electric motors, dynamos, submarine cables, the electric light, electric railways, the telephone, etc. During this period a list of illustrious names appears as those who made important contributions: William Thomson, Clerk Maxwell, Oliver Heaviside, Kirchoff, Arago, Philip Reis, Elisha Gray, A. E. Dolbear, William Preece, Emile Berliner, D. E. Hughes, Alexander Graham Bell, and others.

Thenceforth electric progress diverged into several paths. Specialization had perforce begun. Separate industries grew up which required the undivided attention of engineers thinking along particular lines of development.

Marking the time when it appeared possible to transmit electric energy from point to point without conducting wires, it may be said that the English physicist, Clerk Maxwell, in 1865, and Heinrich Hertz, in Germany, in 1887, pointed the way to the utility of space as a medium for transmission. Hertz, it appears, set up the first induction coil "wireless" transmitter, detecting the transmitted impulses a few feet away by means of a simple loop of wire broken so that the two ends were separated by a minute air gap.

Four years later (1891) Edouard Branley, in France, devised a microphonic type of wireless detector, or "coherer," improving upon the Hertz loop detector.

The Italian youth, Marconi, in 1895 picking up the loose ends of experiments performed by Oliver Lodge, in England, also of Hertz, of Branley, and of Tesla, assembled what was probably the first practical wireless telegraph transmitter and receiver. Following Marconi's arrival in England, the next year, to demonstrate his system to the British telegraph authorities, progress was rapidly made in telegraphing over distances increasing from a few feet to several miles. Notwithstanding that thenceforth various British, German, French, and American savants engaged in experiments in wireless tele-

raphy, Marconi's name continued to be the one most widely referred to as being the father of the new art.

In America, Nikola Tesla, A. E. Kennelly, M. I. Pupin, Elihu Thomson, R. A. Fessenden, and Prof. Trowbridge, all of them learned scientists, devoted much time to investigations into the phenomena of wireless. Dr. Lee De Forest, who took up the subject in 1899, was destined to attain heights in radio discovery and invention, having an important bearing upon the progress of radio telegraphy and radio telephony, not only in America but throughout the world. Indeed, it was De Forest's invention of the three-electrode vacuum tube, in 1907, which started radio on its astonishing upward climb from the experimental stage to the undreamed-of heights to which it has attained in recent years. Following the advent of the vacuum tube the list of names of engineers identified with radio development became so long that to refer to their work, adequately, would require the writing of a history of radio engineering.

It is a discovery of the greatest value when a student realizes that imagination plays an important part in what he may accomplish, that is new and useful. With a knowledge of the principles involved and with a knowledge of details of any given line of work, a man may be qualified to serve satisfactorily in a routine position, but if he is to forge to the front of his profession, if he is to make forward steps, advancing an art beyond where he found it, it is almost certain that such contributions will be the fruits of exercised imagination.

During the ten years following Marconi's early demonstrations of wireless telegraphy it was common to hear occasional references to possible wireless telephony. A remarkable circumstance is that the engineers engaged in wire telephone work, which by 1905 was a fairly well-developed art, evinced little beyond academic interest in the prospects for space telephony. There were logical reasons for this attitude. A wire circuit carried an electric current from transmitter to receiver which was, by means of the transmitter, modulated according to the requirements of speech, while up to that time wireless telegraph signals were simply disjointed impulses sent out into space in the form of dot-and-dash code elements.

In considering the possibility of radio telephony it was apparent that the damped wave transmitters used for radio telegraphy would not be suitable. In order to obtain successful radio telephone transmission it seemed necessary to set up between transmitter and receiver a continuous stream of electric wave radiation, normally constant in wavelength or amplitude, or both. If there were interruptions (separation between impulses) these would have to be sufficiently minute to permit of speech being transmitted intelligibly. Further, on the stream of radiation it would be necessary to impress, or superimpose, quantitative changes in accordance with the acoustic vibrations (sound frequencies) to be transmitted. Also, a receiver would be required which would give, quantitatively, audible indications of these changes in the character of the incoming wave; that is, reproduce these modulations.

These conditions were not met by the then used methods of wireless transmission employing either induction coils or alternating current transformers. The picture presented was that if the wire conductor were dispensed with, it would, of course, be necessary to establish in its place between transmitter and receiver a continuous stream of radiation which could be modulated for the purposes of articulate speech.

Thus it came about that imaginative minds tackled the problem of devising methods of producing generators of continuous currents of such frequencies as would serve as "carriers" of the modulated characteristics effected by a voice actuated telephone transmitter, or microphone. The first steps in this direction were taken in 1906-1907. As a source of continuous oscillations the electric arc was introduced, and developed by V. Poulsen, Pedersen, Dudell, A. Frederick Collins, and others. The continuous stream of oscillations generated by the arc could be modulated for the purposes of telephony, but there was room for betterment.

High-frequency machine generators were introduced by R. A. Fessenden, Rudolph Goldschmidt, E. F. W. Alexanderson, and others. Fessenden, particularly, had early good results employing one of these generators for radio telephony over a distance of eleven miles. Later types of these high-frequency machine generators were used until recent years for long-distance radio telegraphy.

De Forest's vacuum tube, the audion, introduced in its three-electrode form in 1907, was employed as

a detector, replacing, or at least being a fair substitute for, coherers, crystal detectors, magnetic detectors, electrolytic detectors, and other devices then used as a main element of radio receivers. Up to the year 1912, however, the audion contained an undisclosed secret, an undiscovered phenomenon. Discoveries made in 1912-1913 disclosed that it might also be employed as a generator of electric oscillations. Here, then, was a comparatively small, inexpensive device suitable to take the place of previously used alternating current transformers, induction coils, and electric arc generators.

The tubes available in 1913, and the transmitting circuits in which they were associated, permitted generating signaling currents of limited energy, but later improvements made practicable the production of tubes rivaling in output the massive alternators employed in trans-ocean radio telegraphy; and for radio telephony the tube oscillator supplied the element previously missing if transmitters were to be set up anywhere other than in locations where huge power plants might be erected.

The interval of the World War, while it almost completely stifled commercial extensions and applications of the new developments in radio telegraphy and radio telephony, actually served as a spur to further technical gains. The needs of war, both on land and at sea, called for easily portable equipment, for highly selective receivers, for multi-stage amplifiers of very weak received signals, for transmitters capable of working over very long ranges, and for vacuum tubes which could withstand

the hazards of rough treatment in shipping and in being transported from place to place in service.

A result of this was that after the close of the war the various nations had in being a great new utility for which it was supposed for a time that no peacetime use existed. For commercial communication purposes on land there were available long established, efficient systems of wire service for telegraph and telephone needs. Naturally, radio telegraph service was considerably extended in ship service, and inter-continental radio telegraph circuits, which had been used for military, naval, and inter-governmental communication, were turned back to commercial interests for operation, much bettered in equipment and in serviceability.

Most persons now are familiar with the recorded history that, within a year after the close of the war, a new and vastly important use had been found for radio telephony; a service which was not competitive with any other service, and one which brought into the homes of the world at all hours of the day and evening, news of the hour, instruction in world and in local affairs, music and entertainment of seemingly endless variety. Broadcasting with all of its potentialities for changing the routine of home life came into being and continues to expand in usefulness until a time has arrived when a radio receiver is regarded as an indispensable fixture in a home, even where the home consists of but a single room.

While in Great Britain the term "wireless" continues to be commonly employed, in America

“radio” became the accepted term following the adoption of the word by the Berlin convention of 1906. To-day the term covers various utilities, such as radio telegraphy, radio telephony, radio direction finding, radio compasses, radio control, radio television, radio beacons, and so on.

In our times one often hears the remark: “In radio development only the surface so far has been scratched.” If this is true, and one recalls that the radio manufacturing business alone has become one of the major industries of the country, ranking with the railway car building industry; that radio broadcasting has become a huge new industry; that one-third of the trans-Atlantic message traffic is now handled by radio telegraphy; that one-half of the trans-Pacific message traffic is so handled; that millions of radiograms each year are handled between ships, and between ships and shore stations; that radio telegraph and radio telephone have made night flying of airplanes safe and practical; and that the vacuum tube in many new applications promises revolutionary advances in many unrelated industries; then little imagination is required to sense an enlarged measure of usefulness for the devices and systems yet to be developed by those who acquire a working knowledge of the principles of radio.

The radio student will be wise to realize the importance of mastering the fundamentals, the principles of electro-magnetic wave transmission and reception. It is important to become familiar with the circuits and apparatus necessary for operation

on various wavebands, from the ultra high-frequencies of a wavelength less than a meter, to the waves ten miles or more in length. A sure knowledge of these elements will entail studies in the right direction and of the most direct use.

A handwritten signature in cursive script, appearing to read "A. M. Pierce". The signature is written in dark ink on a white background.

Roselle Park, N. J.

February 1, 1933

THE RADIO AMATEUR'S HANDBOOK

CHAPTER I

HOW TO BEGIN RADIO

IN writing this book it is taken for granted that you are: *first*, one of the many millions of persons in the United States who are interested in radio telegraphy and telephony; *second*, that you would like to install an apparatus in your home, and *third*, that it is all new to you.

Now if you live in a city or town large enough to support an electrical supply store, there you will find the necessary apparatus on sale, and someone who can tell you what you want to know about it and how it works. If you live away from the marts and hives of industry you can send to various makers of radio apparatus for their catalogues and price-lists and these will give you much useful information. But in either case it is the better plan for you to know before you start in to buy an outfit exactly what apparatus you need to produce the result you have in mind, and this you can gain in easy steps by reading this book.

Kinds of Radio Systems.—There are two distinct kinds of radio systems and these are: the *radio telegraph* system, and the *radio telephone* system. The

difference between the radio telegraph and the radio telephone is that the former transmits messages by means of a *telegraph key*, and the latter transmits conversation and music by means of a *microphone transmitter*. In other words, the same difference exists between them in this respect as between the Morse telegraph and the Bell telephone.

Parts of a Radio System.—Every complete radio station, whether telegraph or telephone, consists of three chief separate and distinct parts and these are: (a) the *aerial wire system*, or *antenna* as it is often called, (b) the *transmitter*, or *sender*, and (c) the *receiver*, or, more properly, the *receptor*. The aerial wire can be the same for either radio telegraphy or telephony. The transmitter of a radio telegraph set uses a *spark gap* or vacuum tube for setting up the electric oscillations, while for radio telephony a *vacuum tube* is employed for this purpose. The receiver for radio telegraphy and telephony is the same and may include either a *crystal detector* or a *vacuum tube detector*, as will be explained presently.

The Easiest Way to Start.—First of all you must obtain a Government license to operate a sending set, but you do not need a license to put up and use a receiving set, though you are required by law to keep secret any messages which you may overhear. Since no license is needed for a receiving set the easiest way to break into the radio game is to put up an aerial and hook up a receiving set to it; you can then listen-in and hear what is going on in the all-pervading ether around you, and you will soon find enough to make things highly entertaining.

It seems quite unnecessary to mention the fact that this ether all about us is filled from early morning until after midnight with all sorts of music from jazz to grand opera; from vaudeville entertainers to the inaugural speeches of our presidents; in fact *everything* worth knowing about can be heard through a radio headset or loud speaker connected to a receiver. Then by simply shifting the slide on your tuning coil you can often tune-in someone who is sending *Morse*, that is, messages in the dot and dash code, or, perhaps a friend who has a radio telephone transmitter and is talking. Of course, if you want to *talk back* you must have a radio transmitter, either telegraphic or telephonic, and this is a much more expensive part of the apparatus than the receiver, both in its initial cost and in its operation. A radio telegraph transmitter is less costly than a radio telephone transmitter and it is a very good scheme for you to learn to send and receive telegraphic messages.

At the present time, however, there are nearly a hundred amateur receiving stations in the United States to every sending station, so you can see that the majority of radio enthusiasts care more for listening-in to the broadcasting of news and music than to sending out messages on their own account. The easiest way to begin radio, then, is to put up an aerial and hook up a receiving set to it.

About Aerial Wire Systems.—To the beginner who wants to install a radio station the aerial wire system usually looms up as the biggest obstacle of all, and especially is this true if his house is without

a flag pole, or other elevation from which the aerial wire can be conveniently suspended.

If you live in the congested part of a big city where there are no yards and, particularly, if you live in a flat building or an apartment house, you will have to string your aerial wire on the roof, and to do this you should get the owner's, or agent's, permission. This is usually an easy thing to do where you only intend to receive messages, for one or two thin wires supported at either end of the building are all that are needed. If for any reason you cannot put your aerial on the roof then run a wire along the building outside of your apartment, and, finally, if this is not feasible, connect your receiver to a wire strung up in your room, or even to an iron or a brass bed, and you can still get the near-by stations.

An important part of the aerial wire system is the *ground*; that is, your receiving set must not only be connected with the aerial wire, but with a wire that leads to and makes good contact with the moist earth of the ground. Where a house or a building is piped for water or steam, it is easy to make a ground connection, for all you have to do is to fasten the wire to one of the pipes with a clamp. Where the house is isolated, then a lot of wires or a sheet of copper or of zinc must be buried in the ground at a sufficient depth to insure their being kept moist.

About the Receiving Apparatus.—You can either buy the parts of the receiving apparatus separate and hook them up yourself, or you can buy the apparatus already assembled in a set which is, in the beginning, perhaps, the better way.

The simplest receiving set consists of (1) a *detector*, (2) a *tuning coil*, and (3) a *telephone receiver* and these three pieces of apparatus are, of course, connected together and are also connected to the aerial and ground as the diagram in *Fig. 1* clearly shows. There are two chief kinds of detectors used

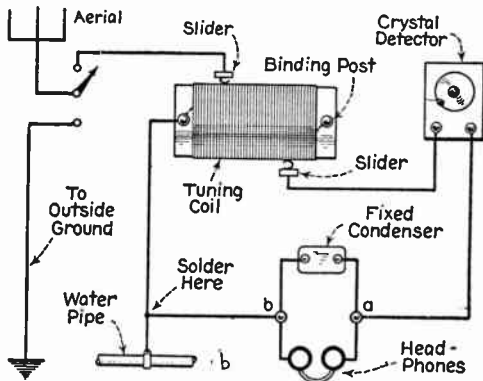


FIG. 1.—Picture diagram of a simple receiving set using a crystal detector. See *Fig. 19* for schematic diagram.

at the present time and these are: (a) the *crystal detector*, and (b) the *vacuum tube detector*. The crystal detector is the cheapest and simplest, but it is not as sensitive as the vacuum tube detector and it requires frequent adjustment. A crystal detector can be used with or without a battery, while the vacuum tube detector requires two small batteries.

A tuning coil of the simplest kind consists of a single layer of copper wire wound on a cylinder with an adjustable, or sliding, contact, but for sharp tuning you need a *loose coupled tuning coil*. Where a single coil tuner is used a *fixed condenser* should be con-

nected around the telephone receivers. Where a loose coupled tuner is employed you should have a variable condenser connected across the *closed oscillation circuit* and a *fixed condenser* across the telephone receivers.

When listening-in to distant stations the energy of the received radio waves is often so very feeble that in order to hear distinctly an *amplifier* must be used. To amplify the incoming sounds a vacuum tube made like a detector is used and sometimes as many as half-a-dozen of these tubes are connected in the receiving circuit, or in *cascade*, as it is called, when the sounds are *amplified*, that is magnified, many hundreds of times.

The telephone receiver of a receiving set is equally as important as the detector. A single receiver can be used but a pair of receivers connected with a head-band gives far better results. Then again the higher the resistance of the receivers the more sensitive they often are and those wound to as high a resistance as 3,200 ohms are made for use with the best sets. To make the incoming signals, conversation or music, audible to a room full of people instead of to just yourself you must use what is called a *loud speaker*. In its simplest form this consists of a metal cone like a megaphone to which is fitted a telephone receiver.

About Transmitting Stations—Getting Your License.—If you are going to install a radio sending apparatus, either telegraphic or telephonic, you will have to secure a Government license for which no fee or charge of any kind is made. There are three

classes of licenses issued to amateurs who want to operate transmitting stations and these are: (1) the *restricted amateur license*, (2) the *general amateur license*, and (3) the *amateur extra first grade license*.

If you are going to set up a transmitter within five nautical miles of any naval radio station then you will have to get a *restricted amateur license* which limits the power you use to half a *kilowatt*¹ and the wavelength you send out to 200 *meters* or under. Should you live outside of the five-mile range of a navy station then you can get a *general amateur license* and this permits you to use a power of 1 kilowatt, but you are likewise limited to a wavelength of 200 meters or less. But if you can show that you are doing some special kind of work and not using your sending station for the mere pleasure you are getting out of it you may be able to get an *amateur extra first grade license*, which gives you the right to send out on wavelengths of from 150 to 220 meters providing you use what is known as a pure continuous wave.

When you are ready to apply for your license write to the *Radio Inspector* of whichever one of the following districts you live in:

| | |
|---------------------|---------------------|
| First District..... | Boston, Mass. |
| Second " | New York City |
| Third " | Baltimore, Md. |
| Fourth " | Norfolk, Va. |
| Fifth " | New Orleans, La. |
| Sixth " | San Francisco, Cal. |
| Seventh " | Seattle, Wash. |
| Eighth " | Detroit, Mich. |
| Ninth " | Chicago, Ill. |

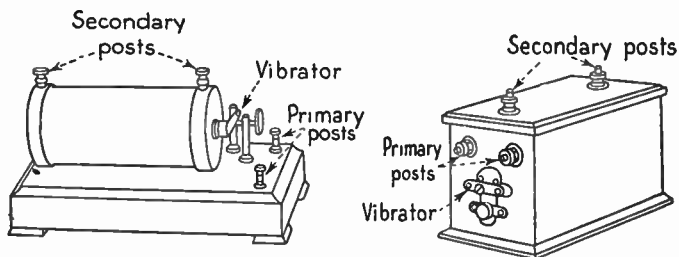
¹ A *kilowatt* is 1,000 *watts*. There are 746 *watts* in a horsepower.

Kinds of Transmitters.—There are two general types of transmitters used for sending out radio messages and these are: (1) radio *telegraph* transmitters, and (2) radio *telephone* transmitters. Telegraph transmitters may use either: (a) a *jump-spark*, (b) an *electric arc*, or (c) a *vacuum tube* apparatus for sending out dot and dash messages, while telephone transmitters may use either: (a) an *electric arc*, or (b) a *vacuum tube* for sending out vocal and musical sounds. The *jump spark* type of telegraph transmitter has given way to the *vacuum tube*, which is more efficient in operation and economical as to upkeep. The amateur of to-day uses vacuum tubes for the transmission of both telegraph and telephone.

The Spark Gap Radio Telegraph Transmitter.—The simplest kind of a radio telegraph transmitter consists of: (1) a *source of direct or alternating current*, (2) a *telegraph key*, (3) a *spark coil* or a *transformer*, (4) a *spark gap*, (5) an *adjustable condenser* and (6) an *auto-transformer*. Where *dry cells* or a *storage battery* must be used to supply the current for energizing the transmitter a spark coil can be employed which may be had in various sizes from a little fellow which gives a $\frac{1}{4}$ -inch spark up to a larger one which gives a 6-inch spark. Where more energy is needed it is better practice to use a transformer and this can be worked on an alternating current of 110 volts, or if only a 110-volt direct current is available then an *electrolytic interrupter* must be used to make and break the current. See coils in *Fig. 2*.

A radio key is made like an ordinary telegraph key except that where large currents are to be used

it is somewhat heavier and is provided with large silver contact points. Spark gaps for amateur work are usually of: (1) the *plain* or *stationary type*, (2) the *rotating type*, and (3) the *quenched gap type*. The plain spark gap is more suitable for small spark coil sets, and it is not so apt to break down the transformer and condenser of the larger sets as the rotary gap. The rotary gap on the other hand tends to prevent *arcing* and so the break is quicker and there is



A- Base type of spark coil

B- Box type of spark coil

FIG. 2 A and B.—Two types of spark coils.

less dragging of the spark. The quenched gap is more efficient than either the plain or rotary gap and moreover it is noiseless.

Condensers for spark telegraph transmitters can be ordinary Leyden jars or glass plates coated with tin or copper foil and set into a frame, or they can be built up of mica and sheet metal embedded in an insulating composition. The glass plate condensers are the cheapest and will serve the purpose well, especially if they are immersed in oil. Tuning coils, called *transmitting inductances* and *oscillation transformers*, are of various types. The simplest kind is

an *auto-transformer* which consists of 25 or 30 turns of copper wire wound on an insulating tube or wound "on air." An *oscillation transformer* is a loose coupled tuning coil and it consists of a primary coil formed of a number of turns of copper wire wound on a fixed insulating support, and a secondary coil of about twice the number of turns of copper wire which is likewise

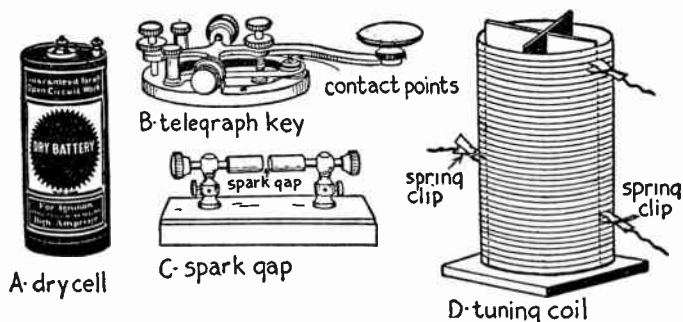


FIG. 3.—Several pieces of apparatus for a small transmitter.

fixed in an insulating support, but the coils are relatively movable.

It is far better practice to use an *oscillation transformer* instead of an *auto-transformer*. The Government regulations regarding "the use of sharp wave" render it difficult to keep within the legal *decrement* of waves when using an auto-transformer.¹ An oscillation transformer enables you to adjust your set so that it will send out a very sharp wave. This will not only prevent its interfering with other amateur stations, but also—what is of greater importance—with the big broadcasting stations.

¹ See Radio Laws, 1912, Section IV, Regulation 4.

The Vacuum Tube Telegraph Transmitter.—This consists of: (1) a *source of direct or alternating current*, (2) a *telegraph key*, (3) a *vacuum tube oscillator*, (4) a *tuning coil*, and (5) a *condenser*. This kind of a transmitter sets up *sustained* oscillations instead of *periodic* oscillations which are produced by a spark gap set.

The Radio Telephone Transmitter.—Because a jump-spark sets up *periodic oscillations*, that is, the oscillations are discontinuous, it cannot be used for radio telephony. An electric arc or a vacuum tube sets up *sustained* oscillations, that is, oscillations which are continuous. As it is far easier to keep the oscillations going with a vacuum tube than it is with an arc the former means has entirely supplanted the latter for radio telephone transmitters. The apparatus required and the connections used for telephone sets will be described in later chapters.

CHAPTER II

PUTTING UP YOUR AERIAL

As inferred in the first chapter, an aerial for receiving does not have to be nearly as well made or put up as one for sending. But this does not mean that you can slipshod the construction and installation of it, for however simple it is, the job must be done right and in this case it is as easy to do it right as wrong.

To send radio telegraph and telephone messages to the greatest distances and to receive them as distinctly as possible from the greatest distances you must use for your aerial (1) copper or aluminum wire, (2) one or more wires, (3) have them the proper length, (4) have them as high in the air as you can, (5) have them in proper relation to each other, and (6) have them well insulated from their supports. If you live in a flat building or an apartment house you can string your aerial wires from one edge of the roof to the other and support them by wooden stays as high above it as may be convenient.

Should you live in a detached house in the city you can usually get your next-door neighbor to let you fasten one end of the aerial to his house and this will give you a good stretch and a fairly high aerial. In the country you can stretch your wires between the house and barn or the windmill. From this you

will see that no matter where you live you can nearly always find ways and means of putting up an aerial that will serve your needs without going to the expense of erecting a mast.

Kinds of Aerial Wire Systems.—An amateur radio aerial can be anywhere from 25 feet to 100 feet long and if you can get a stretch of the latter length and a height of from 30 to 75 feet you will have one

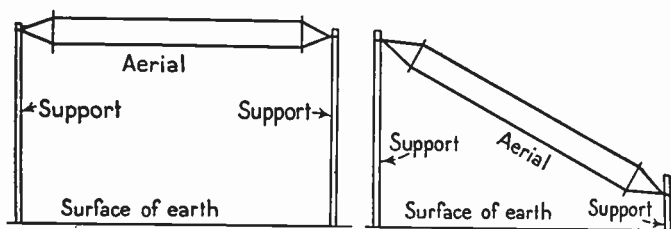


FIG. 4A.—A flat-top or horizontal aerial.

FIG. 4B.—An inclined aerial.

with which you can receive a thousand miles or more and send out as much energy as the Government will allow you to send.

The kind of an aerial that gives the best results is one whose wire, or wires, are *horizontal*, that is, parallel with the earth under it as shown at *A* in *Fig. 4*. If only one end can be fixed to some elevated support then you can secure the other end to a post in the ground, but the slope of the aerial should not be more than 30 or 35 degrees from the horizontal at most as shown at *B*.

The *lead-in wire*, that is, the wire that leads from and joins the aerial wire with your sending and receiving set, can be connected to the aerial anywhere it is most convenient to do so, but the best results are had

when it is connected to one end as shown at *A* in *Fig. 5*, in which case it is called an *inverted L aerial*, or when it is connected to it at the middle as shown at *B*, when it is called a *T aerial*. The lead-in wire must be carefully insulated from the outside of the building and also where it passes through the wall to the inside. This is done by means of an insulating tube known as a *lead-in insulator*, or *bulkhead insulator*, as it is sometimes called.

As a protection against lightning burning out your instruments you can use either: (1) an *air gap light-*

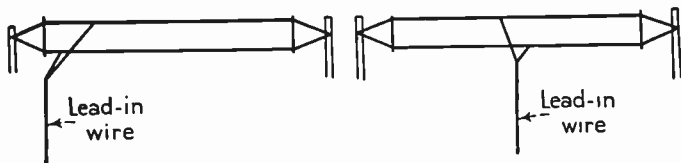
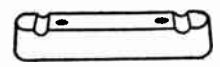


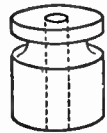
FIG. 5A.—Inverted L aerial.

FIG. 5B.—T aerial.

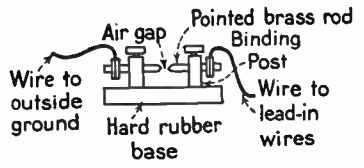
ning arrester, (2) a *vacuum tube protector*, or (3) a *lightning switch*. Whichever of these devices is used it is connected in between the aerial and a ground wire so that a direct circuit to the earth will be provided at all times, except when you are sending or receiving. So your aerial instead of being a menace really acts during an electrical storm like a lightning rod and it is therefore a real protection. The air gap and vacuum tube lightning arresters are little devices that can be used only where you are going to receive, while the lightning switch must be used where you are going to send; indeed, in some localities the *Fire Underwriters* require a lightning switch to be used for receiving sets as well as sending sets.



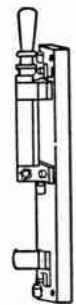
A- Porcelain cleat insulator



B- Porcelain knob insulator



C- Air gap lightning arrester



D- Lightning switch



E- Porcelain tube insulator



F- Ground clamp

FIG. 6.—Some of the necessary equipment for an aerial.

How to Put Up a Cheap Receiving Aerial.—The kind of an aerial wire system you put up will depend, chiefly, on two things, and these are: (1) your pocket-book, and (2) the place where you live.

A Single Wire Aerial.—This is the simplest and cheapest kind of a receiving aerial that can be put up. The first thing to do is to find out the length of wire you need by measuring the span between the two

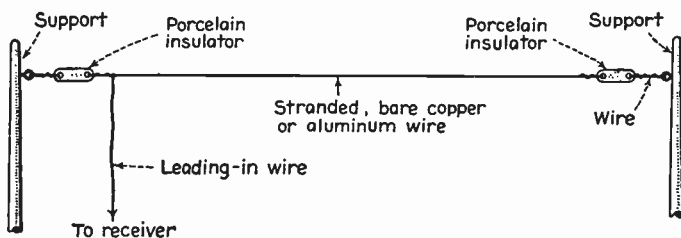


FIG. 7.—A single wire aerial for receiving.

points of support; then add a sufficient length for the lead-in wire and enough more to connect your receiving set with the radiator or water pipe.

You can use any size of copper or aluminum wire that is not smaller than *No. 16 Brown and Sharpe gauge*. When you buy the wire get also the following material: (1) two *porcelain insulators* as shown at *A* in *Fig. 6*; (2) three or four *porcelain knob insulators*, see *B*; (3) either (a) an *air gap lightning arrester*, see *C*, or (b) a *lightning switch*, see *D*; (4) a *lead-in porcelain tube insulator*, see *E*, and (5) a *ground clamp*, see *F*.

To make the aerial, slip each end of the wire through a hole in each insulator and twist it fast; next cut off and slip two more pieces of wire through the other holes in the insulators and twist them fast

and then secure these to the supports at the ends of the building. Take the piece you are going to use for the lead-in wire, twist it around the aerial wire and solder it there as indicated in *Fig. 7*. Now

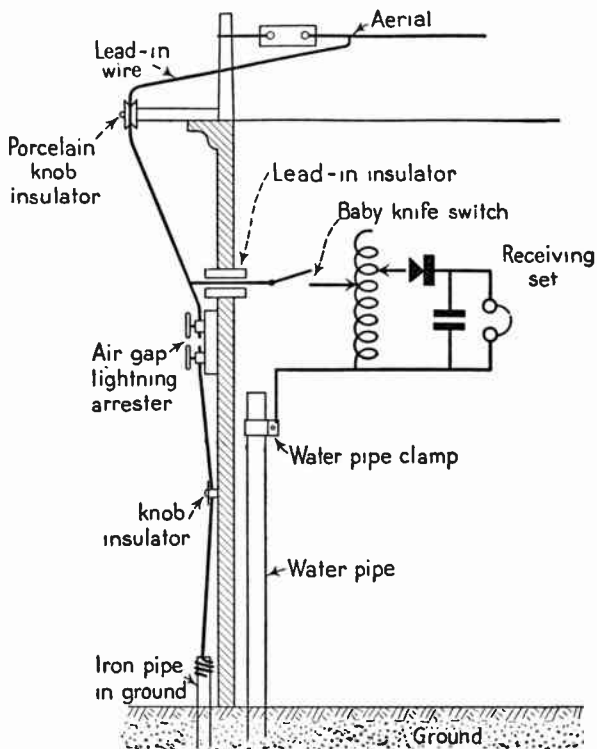


FIG. 8.—Aerial installation showing air-gap lightning arrester.

if you intend to use the *air gap lightning arrester* fasten it to the wall of the building outside of your window, and bring the lead-in wire from the aerial to the top binding post of your arrester and keep it clear of everything as shown at *Fig. 8*. If your aerial

is on the roof and you have to bring the lead-in wire over the cornice or around a corner fix a porcelain knob insulator to the one or the other and fasten the wire to it.

Next bore a hole through the frame of the window at a point nearest your receiving set and push a porcelain tube $5/8$ inch in diameter and 5 or 6 inches long,

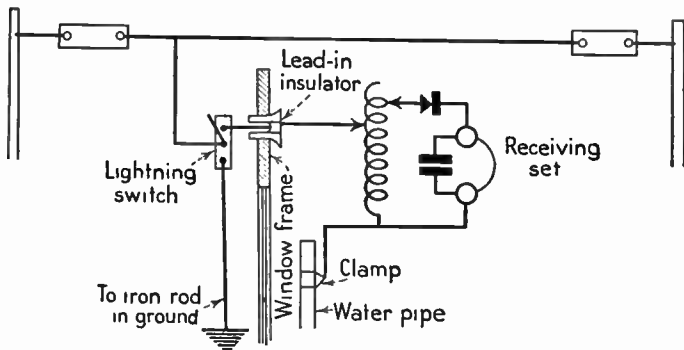
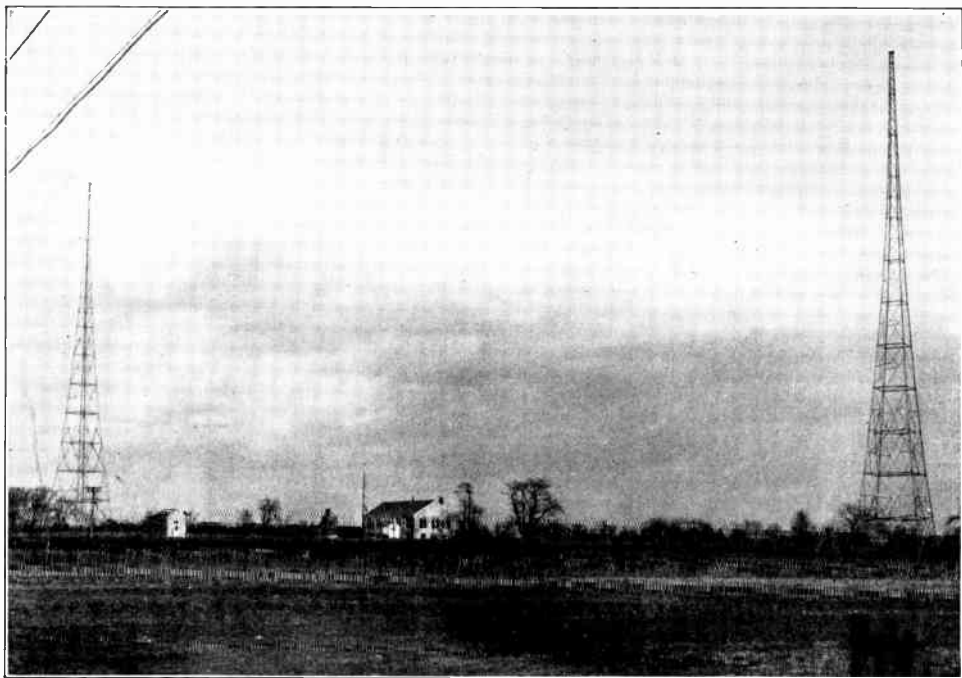


FIG. 9.—Aerial for receiving, using lightning switch instead of arrester. through it. Connect a length of wire to the top post of the arrester or just above it to the wire, run this through the lead-in insulator and connect it to the aerial post of your set. Screw the end of a piece of heavy copper wire to the lower post of the arrester and run it to the ground, on porcelain knobs if necessary, and solder it to an iron rod or pipe, which you have driven into the earth. Finally connect the "ground" binding post of your set with the water pipe or radiator inside of the house by means of the ground clamp, as shown in the diagrammatic sketch in *Fig. 8* and you are ready to tune-in.

If you want to use a lightning switch instead of the



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The antenna towers and transmitter of station WEAJ on Long Island.

air gap arrester then fasten it to the outside wall instead of the latter and screw the free end of the lead-in wire from the aerial to the middle post of it as shown in *Fig. 9*. Run a wire from the top post through the lead-in insulator and connect it with the "aerial" binding post of your set. Next screw one end of a length of heavy copper wire to the lower post of the aerial switch and run it to an iron pipe in the ground, as described above in connection with the spark gap lightning arrester; then connect the "ground" binding post of your set with the radiator or water pipe and your aerial wire system will be complete as shown in *Fig. 9*.

A Two-wire Aerial.—An aerial with two wires will give better results than a single wire for purposes of transmitting and three wires are better than two, but you must keep them well apart. To put up a two-wire aerial get (1) enough *No. 16*, or preferably *No. 14*, solid or stranded copper or aluminum wire, (2) four porcelain insulators, see *B* in *Fig. 6*, and (3) two sticks about 1 inch thick, 3 inches wide and 3 or 4 feet long, for the *spreaders*, and bore one 1/8-inch hole through both ends of each one. Now twist the ends of the wires to the insulators and then cut off four pieces of wire about 6 feet long and run them through the holes in the wood spreaders. Finally twist the ends of each pair of short wires to the free ends of the insulators and then twist the free ends of the wires together.

For the lead-in wire that goes to the lightning switch take two lengths of wire and twist one end of each one around the aerial wires and solder them

there. Twist the short wire around the long wire and solder this joint also when the aerial will look like *Fig. 10*. Bring the free end of the lead-in wire down to the middle post of the lightning switch and fasten it there and connect up the receiver to it and the ground as described under the caption of *A Single Wire Aerial*.

Connecting in the Ground.—If there is a water system or a steam-heating plant in your house you

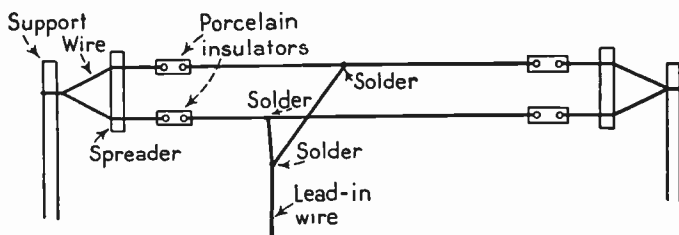


FIG. 10.—A two-wire aerial.

can make your ground connection by clamping a ground clamp to the nearest pipe as has been previously described. Connect a length of bare or insulated copper wire with it and bring this up to the table on which you have your receiving set. If there are no grounded pipes available then you will have to make a good ground which we shall describe presently and lead the ground wire from your receiving set out of the window and down to it.

The aerials heretofore described are satisfactory for receiving purposes, but if you are going to transmit also then other factors must be taken into consideration.

As the tendency now is for amateurs to use wave-

lengths under 100 meters and if you are going to operate in this field, you will require an aerial that will function at maximum efficiency on these low waves. As has been mentioned previously, the simplest of all aerials is one having but a single wire.

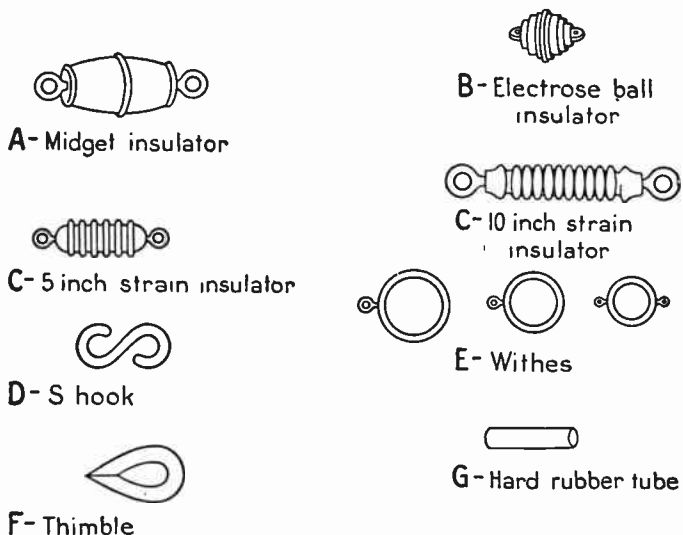


FIG. 11.—Different types of hardware for aerials.

For short waves the simplest is the best and so you will have little difficulty in the antenna system.

Let us assume that you are going to transmit in the 50-meter band. For maximum radiation, or distance that you can transmit, you will require an antenna 40 feet long and a counterpoise of the same length. It should be remembered that in calculating the length of an antenna the lead-in wire must be

included. In other words, the wire from the further insulator to the set itself must measure 40 feet, *not* just the length of wire between the two insulators.

The counterpoise in transmitting is used instead of a regular ground connection and is a wire, in this case, put up just like the aerial wire, insulated as

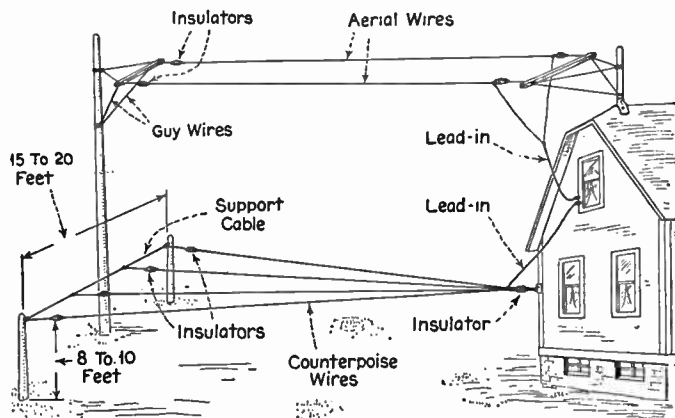


FIG. 12.—One or more counterpoise wires can be employed with any type of aerial for transmitting.

carefully and run directly under the aerial and high enough from the ground so that it will not interfere with anything passing beneath it. See *Fig. 12*.

It is difficult to give any hard and fast rules for the exact lengths of antenna systems without going into extensive mathematics, but an approximate idea may be had by remembering that the wavelength on which you are operating and the length of the antenna should be about the same. Of course, the natural wavelength of the antenna can be lowered by connecting a variable condenser in *series*.

The Cage Antenna.—This type of antenna system consists of a number, generally six, of wires of equal length spaced at equal intervals around a hoop of some insulating material. These hoops may be anywhere from 6 to 10 inches in diameter. The wires are brought together at each end as shown and the lead-in taken from the most convenient end. The lead-in is also of similar construction to the antenna; that is, it consists of several wires running parallel and spaced about hoops 3 inches in diameter. Just before the lead-in reaches the building, these wires are brought together and soldered to a single wire, which is brought into the set. The length of this type of aerial should be about 60 feet for operation on the 50 meter band.

An easily constructed counterpoise is one of four wires spread out fan shape. It is more efficient to have the counterpoise immediately under the aerial, but not absolutely necessary. The counterpoise wires should be just far enough off the ground so that they will not interfere with anything passing under them. Let us say, if they are on a lawn they should be about 8 to 10 feet from the earth.

From a central rod the wires of the same length as the aerial are run to four other poles spaced about 3 feet apart, these being under the aerial, as shown in the illustration. The counterpoise lead-in wire is connected to the central post where the wires meet.

For these aerials any one of a number of kinds of wire can be used and among these are (a) *stranded copper wire*; (b) *braided copper wire*; (c) *stranded silicon bronze wire*, and (d) *stranded phosphor-bronze wire*.

Stranded and braided copper wire is very flexible as it is formed of seven strands of fine wire twisted or braided together and it is very good for short and light aerials. Silicon bronze wire is stronger than copper wire and should be used where aerials are more than 100 feet long, while phosphor-bronze wire is the strongest aerial wire made and is used for high grade aerials by the commercial companies and the Government for their high-power stations. Unlike other wires mentioned this wire will not corrode.

CHAPTER III

SIMPLE TELEGRAPH AND TELEPHONE RECEIVING SETS

With a crystal detector receiving set you can receive either telegraphic dots and dashes or telephonic speech and music. You can buy a receiving set already assembled or you can buy the different parts and assemble them yourself. An assembled set is less bother in the beginning, but if you like to experiment you can *hook up*, that is, connect the separate parts together yourself and it is perhaps a little cheaper to do it this way. Then again, by so doing you get a lot of valuable experience in radio work and an understanding of the workings of radio that you cannot get in any other way.

Assembled Radio Receiving Sets.—The cheapest assembled receiving set advertised is one in which the detector and tuning coil are mounted in a box. It costs very little and can be bought of dealers in electrical supplies generally. This includes a crystal detector, an adjustable tuning coil, a single telephone receiver with head-band and the wire, porcelain insulators, lightning switch and ground clamp for the aerial wire system. It will receive radio telegraph and telephone messages over a range of from 10 to 25 miles from either broadcasting or commercial stations.

Another cheap unit receptor, that is, a complete radio receiving set already mounted which can be used with a single aerial is sold for \$25.00. This set includes a vacuum-tube detector, a variable tuning coil, a fixed condenser and a pair of head telephone receivers. It can also be used to receive either telegraph or telephone messages from distances up to 25 miles. The aerial equipment is not included in this price, but it can be obtained at a slight additional cost.

Assembling Your Own Receiving Set.—In this chapter we shall go only into the apparatus used for two simple receiving sets, both of which have a *crystal detector*. The first set includes a *double slide tuning coil* and the second set employs a *loose coupled tuning coil*, or *loose coupler*, as it is called for short. For either set you can use a pair of 2,000- or 3,000-ohm headphones.

The Crystal Detector.—A crystal detector consists of: (1) *the frame*, (2) *the crystal*, and (3) *the wire point* or “cat whisker.” There are any number of different designs for frames, the idea being to provide a device that will (a) hold the sensitive crystal firmly in place, and yet permit of its removal, (b) to permit the *wire point*, or *electrode*, to be moved in any direction so that the free point of it can make contact with the most sensitive spot on the crystal and (c) to vary the pressure of the wire on the crystal.

A simple detector frame is shown in the cross-section at *A* in *Fig. 13*; the crystal, which may be *galena*, *silicon* or *iron pyrites*, is held securely in a holder while the *phosphor-bronze wire point* which

makes contact with it, is fixed to one end of a threaded rod on the other end of which is a knob. This rod screws into and through a sleeve fixed to a ball that sets between two brass standards, and this permits an up and down or a side to side adjustment of the metal point, while the pressure of it on the crystal is regulated by the screw.

A crystal of this kind is often enclosed in a glass cylinder, and this makes it retain its sensitiveness for

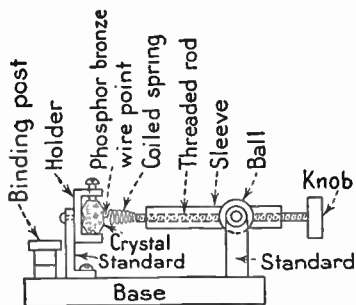


FIG. 13A.—Parts of a crystal detector.

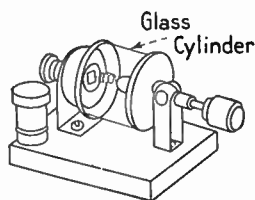


FIG. 13B.—An assembled crystal detector.

a much longer time than if it were exposed to dust and moisture. A horizontal type of this detector is shown at *B* of *Fig. 13*. Galena is the crystal that is generally used, for, while it is not quite as sensitive as silicon and iron pyrites, it is easier to obtain a sensitive piece.

The Tuning Coil.—It is with the tuning coil that you *tune-in* and *tune-out* different stations and this you do by sliding the contacts to and fro over the turns of wire; in this way you vary the *inductance*, which is a *constant* of the receiving circuit and so

adjust the circuit to receive different *electric waves*, that is, radio waves, of different lengths.

The Double Slide Tuning Coil.—With this tuning coil you can receive waves from any station up to 1,000 meters in length. One of the ends of the coil of wire connects with the binding post marked *a* in *Fig. 14* and the other end connects with the other

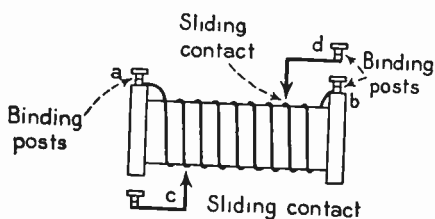


FIG. 14A.—Schematic diagram of double-slide tuning coil.

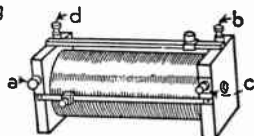


FIG. 14B.—Double-slide tuner with letters indicating terminals as in *Fig. 14A*.

binding post marked *b*, while one of the sliding contacts is connected to the binding post *c*, and the *other sliding contact* is connected with the binding post *d*.

When connecting in the tuning coil, only the post *a* or the post *b* is used as may be most convenient, but the other end of the wire which is connected to a post is left free; just bear this point in mind when you come to connect the tuning coil up with the other parts of your receiving set. The tuning coil is shown complete at *B*. A *triple slide* tuning coil constructed like the double slide tuner just described, only with more turns of wire on it, makes it possible to receive wavelengths up to 1,500 meters.

The Loose Coupled Tuning Coil.—With a *loose coupler*, as this kind of a tuning coil is called for short, very *selective tuning* is possible, which means that you can tune-in a station very sharply and will receive any wavelengths in the range of the coil. The primary coil is wound on a fixed cylinder and its inductance is varied by means of a sliding contact like the double slide tuning coil described above.

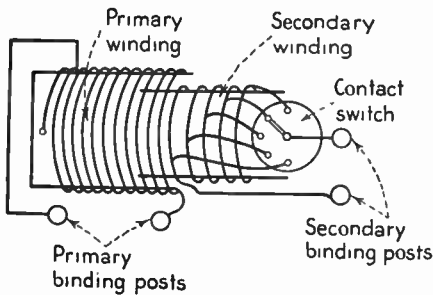


FIG. 15A.—Schematic diagram of a loose coupler.

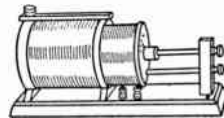


FIG. 15B.—A loose coupler complete.

The secondary coil is wound on a cylinder that slides in and out of the primary coil. The inductance of this coil is varied by means of a switch that makes contact with the fixed points, each of which is connected with every twentieth turn of wire as shown in the diagram A in Fig. 15. The loose coupler is shown complete at B.

Fixed and Variable Condensers.—You do not require a condenser for a simple receiving set, but if you will connect a *fixed condenser* across your headphones you will get better results, while a *variable condenser* connected in the *closed circuit* of a *direct coupled receiving set*, that is, one where a double slide

tuning coil is used, makes it easy to tune very much more sharply. A variable condenser is absolutely necessary where the circuits are *inductively coupled*, that is, where a loose coupled tuner is used.

A fixed condenser consists of a number of sheets of paper or mica with leaves of tin foil in between them

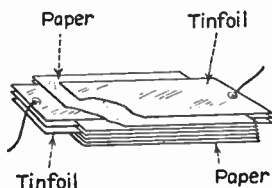


FIG. 16A.—How a fixed condenser is built up.

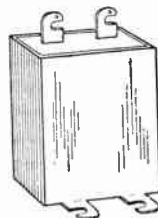


FIG. 16B.—A complete fixed condenser.

and so built up that one end of every other leaf of tin foil projects from the opposite end of the paper as shown at *A* in *Fig. 16*. The paper and tin foil are then

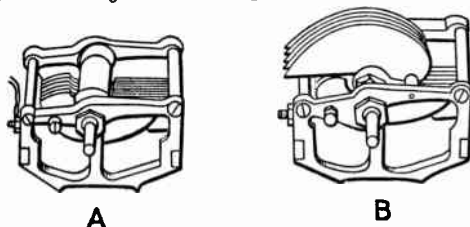


FIG. 17A and B.—A variable condenser with all its movable plates meshed in A and open at B, which shows also the shape of the plates.

pressed together and impregnated with an insulating compound.

A variable condenser, see *Fig. 17*, of the rotating type is formed of a set of fixed semi-circular metal plates which are slightly separated from each other

and between these a similar set of movable semi-circular metal plates is made to interleave; the latter are secured to a shaft on the top end of which is a knob and by turning it the capacity of the condenser, and, hence, of the circuit in which it is connected, is varied.



FIG. 18.—A pair of phones, showing head-band, leads and tips.

About Telephone Receivers.—There are a number of makes of head telephone receivers on the market that are designed especially for radio work. These phones are wound to *resistances* of from 75 *ohms* to 8,000 *ohms*. You can get a receiver wound to any resistance in between the above values, but for either of the simple receiving sets such as described in this chapter you ought to have a pair wound to at least 2,000 *ohms*. A pair of headphones of this type is shown in *Fig. 18*.

Connecting up the Parts for the Receiving Set.—For this set get (1) a *crystal detector*, (2) a *two-slide*

tuning coil, (3) a fixed condenser, and (4) a pair of 2,000-ohm headphones. Mount the detector on the right-hand side of a board and the tuning coil on the left-hand side. Screw in two binding posts for the cord ends of the telephone receivers at *a* and *b* as

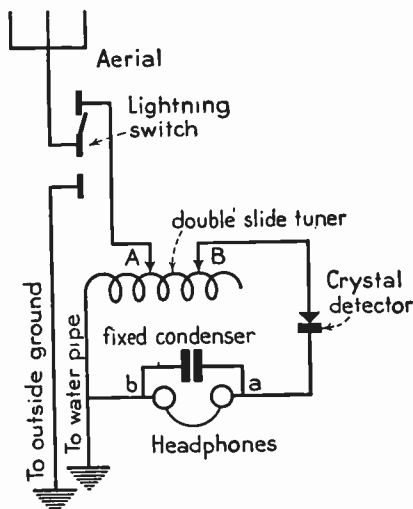


FIG. 19.—Wiring diagram of simple crystal receiver. See also *Fig. 1*.

shown in *Fig. 1*. This done connect one of the end binding posts of the tuning coil with the ground wire, and a post of one of the contact slides with the lightning arrester or switch which leads to the aerial wire.

Now connect the post of the other contact slide to one of the posts of the detector and the other post of the latter with the binding post *a*, then connect the binding post *b* to the ground wire and solder the joint. Next connect the ends of the telephone receiver cord

to the posts *a* and *b*, and connect a fixed condenser also with these posts, all of which are shown in the wiring diagram, and you are ready to adjust the set for receiving. See *Fig. 19*.

A Loose Coupler Receiving Set.—Use the same kind of a detector and a pair of headphones as before, but get (1) a *loose coupled tuning coil*, and (2)

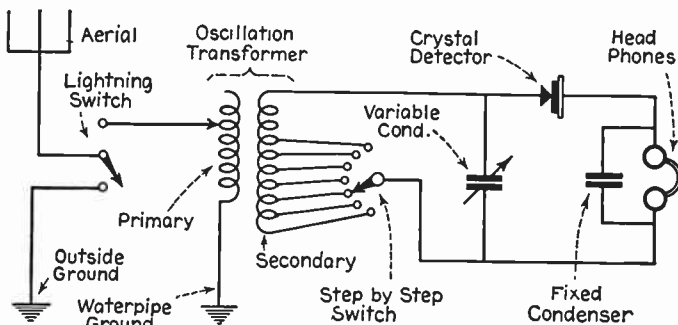


FIG. 20.—Wiring diagram for loose-coupler crystal receiver.

a *variable condenser*. Mount the loose coupler at the back of a board on the left-hand side and the variable condenser on the right-hand side. Then mount the detector in front of the variable condenser and screw two binding posts in front of the tuning coil as shown in *Fig. 20*.

Now connect the post of the sliding contact of the loose coupler with the wire that runs to the lightning switch and thence to the aerial; connect the post of the primary coil, which is the outside coil, with the ground wire; then connect the binding post leading to the switch of the secondary coil, which is the inside coil, with one of the posts of the variable condenser,

and finally, connect the post that is joined to one end of the secondary coil with the other post of the variable condenser.

This done, connect one of the posts of the condenser with one of the posts of the detector, the other post of the detector with a binding post, and the other binding post to the other post of the variable condenser. Next connect a fixed condenser to the binding posts and then connect the telephone receivers to these same posts, all of which is shown in the wiring diagram. You are now ready to adjust the instruments. In making the connections use No. 16 or 18 insulated copper wire and scrape the ends clean where they go into the binding posts. See, also, that all of the connections are tight and where you have to cross the wires keep them apart by an inch or so and always cross them at right angles.

Adjusting the First Set—The Detector.—The first thing to do is to test the detector in order to find out if the point of the contact wire is on a sensitive spot of the crystal. To do this you need a *buzzer*, a *switch* and a *dry cell*. An electric bell from which the gong has been removed will do for the buzzer, but you can get one that is made specially for the purpose, which gives out a clear, high-pitched note that sounds like a high-power station and is known as a high-frequency buzzer.

Connect one of the binding posts of the buzzer with one post of the switch, the other post of the latter with the zinc post of the dry cell and the carbon post of this to the other post of the buzzer. Then connect the post of the buzzer that is joined to the vibrator, to the ground wire as shown in the wiring dia-



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One of the smaller of the eight studios in the National Broadcasting Building, New York City, looking toward the control room and observation booth, the windows of which show in the rear wall.

gram, *Fig. 21*. Now close the switch of the buzzer circuit, put on your headphones, and move the wire point of the detector to various spots on the crystal until you hear the sparks made by the buzzer in your phones.

Then vary the pressure of the point on the crystal

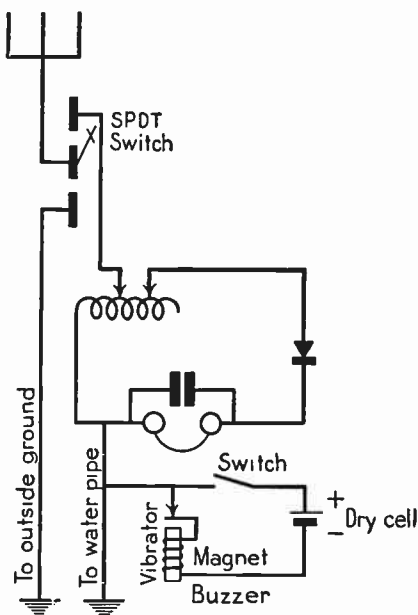


FIG. 21.—Diagram of connections for adjusting the crystal receiver.

until you hear the sparks as loud as possible. After you have made the adjustment, open the switch and disconnect the buzzer wire from the ground wire of your set. This done, be very careful not to jar the detector or you will throw it out of adjustment and then you will have to do it all over again. You are now ready to tune the set with the tuning coil and listen-in.

The Tuning Coil.—To tune this set move the slide *A* of the double slide tuner, see *B* in *Fig. 14*, over to the end of the coil that is connected with the ground wire and the slide *B* near the opposite end of the coil, that is, the one that has the free end. Now move the slide *A* toward the *B* slide and when you hear the dots and dashes, or speech or music, that is coming in as loud as you can move the *B* slide toward the *A* slide until you hear still more plainly. A very few trials on your part and you will be able to tune in or tune out any station you can hear, if not too close or powerful.

Adjusting the Loose Coupler Set.—First adjust the crystal detector with the buzzer set as described above with the other set, then turn the knob of your variable condenser so that the movable plates are just half-way in, pull the secondary coil of your loose coupled tuner half-way out; turn the switch lever on it until it makes a contact with the middle contact point and set the slider of the primary coil half-way between the ends.

Now listen-in for telegraphic signals or telephonic speech or music; when you hear one or the other, slide the secondary coil in and out of the primary coil until the sounds are loudest; now move the contact switch over the points forth and back until the sounds are still louder, then move the slider to and fro until the sounds are yet louder and, finally, turn the knob of the condenser until the sounds are clear and crisp. When you have done all of these things you have, in the parlance of the radio operator, *tuned-in*, and you are ready to receive whatever is being sent.

CHAPTER IV

ELECTRICITY SIMPLY EXPLAINED

It is easy to understand how electricity behaves and what it does if you get the right idea of it at the start. In the first place, if you will think of electricity as being a fluid like water its fundamental actions will be greatly simplified. Both water and electricity may be at rest or in motion. When at rest, under certain conditions, either one will develop pressure, and this pressure when released will cause them to flow through their respective conductors and thus produce a current.

Electricity at Rest and in Motion.—Any wire or a conductor of any kind can be charged with electricity, but a Leyden jar, or other condenser, is generally used to hold an electric charge because it has a much larger *capacitance*, as its capacity is called, than a wire. As a simple analogy of a condenser, suppose you have a tank of water raised above a second tank and that these are connected together by means of a pipe with a valve in it, as shown at *A* in *Fig. 22*.

Now if you fill the upper tank with water and the valve is turned off, no water can flow into the lower tank but there is a difference of pressure between them, and the moment you turn the valve on a current of water will flow through the pipe. In very much the same way when you have a condenser

charged with electricity the latter will be under *pressure*, that is, a *difference of potential* will be set up, for one of the sheets of metal will be charged positively and the other one, which is insulated from it, will be charged negatively, as shown at *B*. On closing the switch the opposite charges rush together

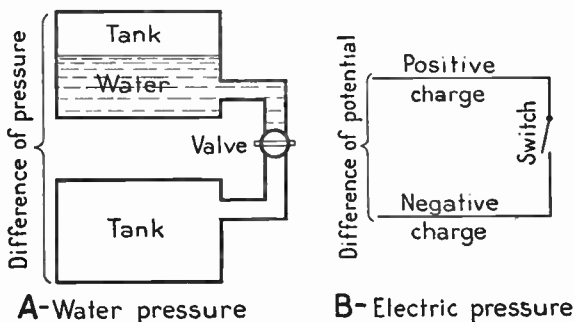
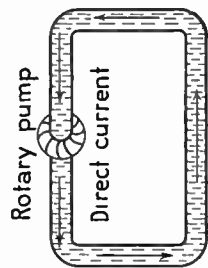


FIG. 22.—Water analogy for electric pressure.

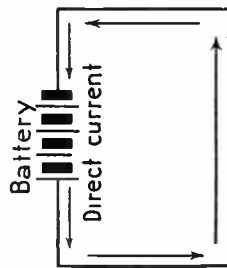
and form a current which flows to and fro between the metal plates.¹

An Electric Current and its Circuit.—Just as water flowing through a pipe has *quantity* and *pressure* back of it and the pipe offers friction which tends to hold back the water, so, likewise, does electricity flowing in a circuit have: (1) *quantity*, or *current strength*, or just *current*, as it is called for short, or *amperage*, and (2) *pressure*, or *potential difference*, or *electromotive force*, or *voltage*, as it is variously called, and the wire, or circuit, in which the current is flowing has (3) *resistance* which tends to hold back the current.

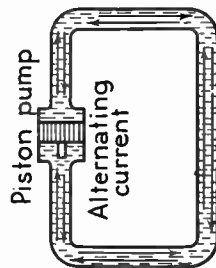
¹ Strictly speaking, it is the difference of potential that sets up the electromotive force.



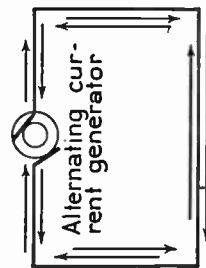
A-Water flowing in a loop of pipe



B-Electric current flowing in a closed circuit



C-Water alternating in direction in pipe



D-Alternating current flowing in closed circuit

FIG. 23.—Water analogies for direct and alternating currents.

A definite relation exists between the current, the electromotive force and the resistance of the circuit; and if you will get this relationship clearly in your mind you will have a very good insight into how direct and alternating currents act. To keep a quantity of water flowing in a loop of pipe, which we will call the circuit, pressure must be applied to it and this may be done by a rotary pump as shown at *A* in *Fig. 23*; in the same way, to keep a quantity of electricity flowing in a loop of wire, or circuit, a battery or other means for generating electric pressure must be used, as shown at *B*.

If you have a closed pipe connected with a piston pump, as at *C*, as the piston moves to and fro the water in the pipe will move first one way and then the other. So also when an alternating current generator is connected to a wire circuit, as at *D*, the current will flow first in one direction and then in the other, and this is what is called an *alternating current*.

Current and the Ampere.—The amount of water flowing in a closed pipe is the same at all parts of it and this is also true of an electric current, in that there is exactly the same quantity of electricity at one point of the circuit as there is at any other.

The amount of electricity, or current, flowing in a circuit in a second is measured by a unit called the *ampere*,¹ and it is expressed by the symbol *I*.² Just to give you an idea of the quantity of current in an *ampere*, we will say that a dry cell when fresh gives a current of about 20 amperes. To measure the current

¹ For definition of *ampere* see *Appendix*.

² This is because the letter *C* is used for the symbol of *capacity*.

in amperes an instrument called an *ammeter* is used, as shown at *A* in *Fig. 24*, and this is always connected in *series* with the line, as shown at *B*.

Electromotive Force and the Volt.—When you have a pipe filled with water or a circuit charged with

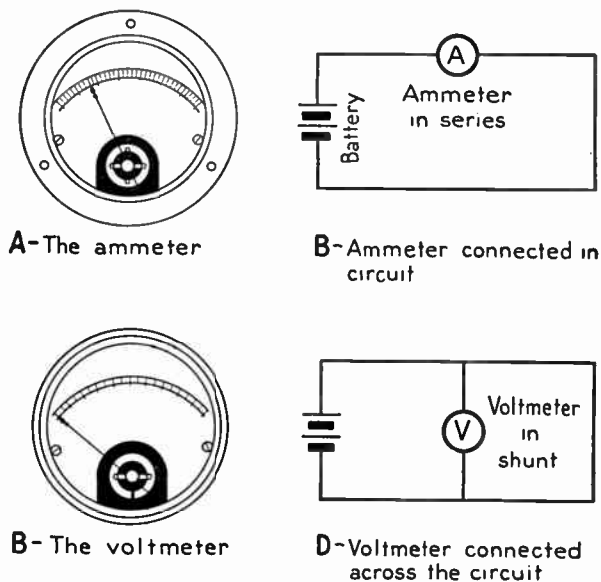
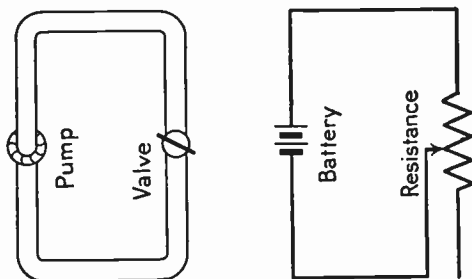


FIG. 24.—How the ammeter and voltmeter are used.

electricity and you want to make them flow you must use a pump in the first case and a battery or a dynamo in the second case. It is the battery or dynamo that sets up the electric pressure as the circuit itself is always charged with electricity.

The more cells you connect together in *series* the greater will be the electric pressure developed and the more current it will move along just as the

amount of water flowing in a pipe can be increased by increasing the pressure of the pump. The unit of electromotive force is the *volt*, and this is the electric pressure which will force a current of *1 ampere* through a resistance of *1 ohm*; it is expressed by the symbol *E*. A fresh dry cell will give a reading of about 1.5 volts. To measure the pressure of a current in volts an instrument called a *voltmeter* is



A—A valve limits the flow of water

B—A resistance limits the flow of current

FIG. 25.—Water valve analogy of electrical resistance.

used, as shown at *C* in *Fig. 24*, and this is always connected across the circuit, as shown at *D*.

Resistance and the Ohm.—Just as a water pipe offers a certain amount of resistance to the flow of water through it, so a circuit opposes the flow of electricity in it and this is called *resistance*. Further, in the same way that a small pipe will not allow a large amount of water to flow through it, so, too, a thin wire limits the flow of the current in it.

If you connect a *resistance coil* in a circuit it acts in the same way as partly closing the valve in a pipe, as shown at *A* and *B* in *Fig. 25*. The resistance of a

circuit is measured by a unit called the *ohm*, and it is expressed by the symbol *R*. A No. 10, Brown and Sharpe gauge soft copper wire, 1,000 feet long, has a resistance of about 1 ohm. To measure the resistance of a circuit an apparatus called a *resistance bridge* is used. The resistance of a circuit can, however, be easily calculated, as the following shows.

What Ohm's Law Is.—If, now, (1) you know that the current flowing in a circuit is in *amperes*, and the electromotive force, or pressure, is in *volts*, you can then easily find what the resistance is in *ohms* of the circuit in which the current is flowing by this formula:

$$\frac{\text{Volts}}{\text{Amperes}} = \text{Ohms, or } \frac{E}{I} = R$$

That is, if you divide the electromotive force in volts by the current in amperes the quotient will give you the resistance in ohms.

Or (2) if you know what the electromotive force of the current is in *volts* and the resistance of the circuit is in *ohms* then you can find what the current flowing in the circuit is in *amperes*, thus:

$$\frac{\text{Volts}}{\text{Ohms}} = \text{Amperes, or } \frac{E}{R} = I$$

That is, by dividing the electromotive force in volts by the resistance of the circuit in ohms you will get the amperes flowing in the circuit.

Finally (3) if you know what the resistance of the circuit is in *ohms* and the current is in *amperes* then you can find what the electromotive force is in *volts* since:

$$\text{Ohms} \times \text{Amperes} = \text{Volts, or } R \times I = E$$

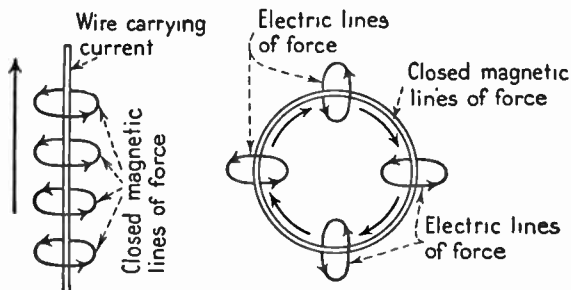
That is, if you multiply the resistance of the circuit in ohms by the current in amperes the result will give you the electromotive force in volts.

From this you will see that if you know the value of any two of the constants you can find the value of the unknown constant by a simple arithmetical process. This relation between these three constants is known as *Ohm's Law* and as it is very important you should memorize it.

What the Watt and Kilowatt Are.—Just as *horse-power* or *H.P.*, is the unit of power indicating the rate at which steam can do work, so the *watt* is the unit of power indicating the rate at which an electric current can perform work. To find the *watts* a current develops you need only to multiply the *amperes* by the *volts*. There are 746 *watts* to 1 *horse-power*, and 1,000 *watts* are equal to 1 *kilowatt*.

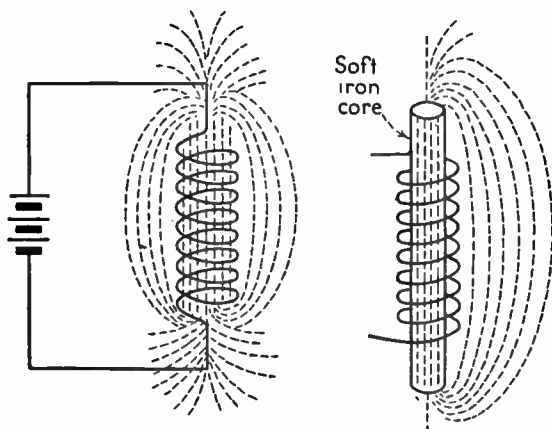
Electromagnetic Induction.—To show that a current of electricity sets up a magnetic field around it you have only to hold a compass over a wire whose ends are connected with a battery when the needle will swing at right angles to the length of the wire. By winding an insulated wire into a coil and connecting the ends of the latter with a battery you will find, if you test it with a compass, that the coil has developed magnetic properties.

This is due to the fact that the energy of an electric current flowing in the wire is partly changed into magnetic lines of force which rotate at right angles about it as shown at *A* in *Fig. 26*. The magnetic field produced by the current flowing in the coil is precisely the same as that set up by a



A-An electric current changed into magnetic lines of force

B-Magnetic lines of force changed into electric lines of force



C-Magnetic lines of force around a coil

D-A core of soft iron concentrates the lines of force

FIG. 26.—Illustrating one of the most important electrical properties of a wire and showing the effect on the magnetic lines of force when an iron core is inserted in the coil.

permanent steel magnet. Conversely, when a magnetic line of force is set up a part of its energy goes to make up electric currents which whirl about in a like manner, as shown at *B*.

Self-induction or Inductance.—When a current is made to flow in a coil of wire the magnetic lines of force produced are concentrated, as at *C*, so that each turn of wire sets up action in the one next to it, and this action is called *self-induction*, *self-inductance* or just *inductance*. The self-induction, or inductance, forms a concentrated *magnetic field*, see *C*, as it is called, and if a bar of soft iron is slipped into the coil it will be magnetized, as at *D*, and it will remain a magnet until the current is cut off.

Mutual Induction.—When two loops of wire, or better, two coils of wire, are placed close together the electromagnetic induction between them is reactive; that is, when a current is made to flow through one of the coils closed magnetic lines of force are set up and when these cut the other loop or turns of wire of the other coil, they in turn produce electric currents in it.

It is the mutual induction that takes place between two coils of wire which makes it possible to transform *low-voltage currents* from a 110-volt source of alternating current into high-pressure currents, or *high-potential currents*, as they are called, by means of a spark coil or a transformer, as well as to *step up* and *step down* the potential of the high-frequency currents that are set up in sending and receiving oscillation transformers. Soft iron cores are not often used in oscillation inductance coils and oscillation trans-

formers, as the frequency of the current is so high the iron, unless very soft and laminated, would not have time to magnetize and demagnetize and so would not help along the mutual induction to any appreciable extent.

High-Frequency Currents.—High-frequency currents, or electric oscillations as they are called, are currents of electricity that surge to and fro in a circuit a million times, more or less, per second. Currents of such high-frequencies will *oscillate*, that is, surge to and fro, in an *open circuit*, such as an aerial system, as well as in a *closed circuit*.

Now there is only one method by which currents of high-frequency, or *radio-frequency*, as they are termed, can be set up by spark or vacuum tube transmitters, and this is by discharging a charged condenser through a circuit having inductance and a small resistance. To charge a condenser a spark coil or a transformer is used and the ends of the secondary coil, which delivers the high-potential alternating current, are connected with the condenser. To discharge the condenser automatically a *spark*, or an *arc*, or the *flow of electrons* in a vacuum tube, is employed.

Constants of an Oscillation Circuit.—An oscillation circuit, as pointed out before, is one in which high-frequency currents surge or oscillate. Now the number of times a high-frequency current will surge forth and back in a circuit depends upon two factors called the constants of the circuit, namely: (1) its *capacity*, and (2) its *inductance*.

What Capacity Is.—The word *capacity* means the *electrostatic capacity* of a condenser or a circuit.

The capacity of a condenser or a circuit is the quantity of electricity which will raise its pressure, or potential, to a given amount. The capacity of a condenser or a circuit depends on its size and form and the materials of which it is made.

The capacity of a condenser or a circuit is directly proportional to the quantity of electricity that will charge it to a given potential. The *farad*, is the unit of capacity and a condenser or a circuit to have a capacity of one farad must be of such size that one *coulomb*, which is the unit of electrical quantity, will raise its charge to a potential of one volt. Since the farad is far too large for practical purposes a millionth of a farad, or *microfarad*, whose symbol is *mfd.*, is used.

What Inductance Is.—Under the sub-caption of *Self-Induction* and *Inductance* in the beginning of this chapter it was shown that it was the inductance of a coil that makes a current flowing through it produce a strong magnetic field, and here, as one of the constants of an oscillation circuit, it makes a high-frequency current act as though it possessed *inertia*.

Inertia is that property of a material body that requires time and energy to set in motion, or stop the body. Inductance is that property of an oscillation circuit that makes an electric current take time to start and time to stop. Because of the inductance, when a current flows through a circuit it causes the electric energy to be absorbed and changes a large part of it into magnetic lines of force. Where high-frequency currents surge in a circuit the inductance of it becomes a powerful factor. The practical unit of

inductance is the *henry* and it is represented by the symbol *L*.

What Resistance Is.—The resistance of a circuit to high-frequency currents is different from that for low-voltage direct or alternating currents, as the former do not sink into the conductor to nearly so great an extent; in fact, they stick practically to the

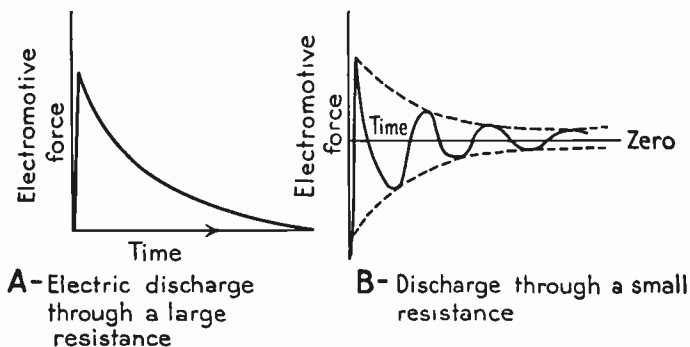


FIG. 27.—The effect of resistance on the discharge of an electric current.

surface of it, and hence their flow is opposed to a very much greater extent. The greater part of the resistance of a circuit to high-frequency currents is generally found in the spark gap, arc gap, or the space between the electrodes of a vacuum tube. The unit of resistance is, as stated, the *ohm*, and its symbol is *R*.

The Effect of Capacity, Inductance and Resistance on Electric Oscillations.—If an oscillation circuit in which high-frequency currents surge has a large resistance, it will so oppose the flow of the currents that they will be damped out and reach zero gradually, as shown at *A* in *Fig. 27*. But if

the resistance of the circuit is small, and in radio circuits it is usually so small as to be negligible, the currents will oscillate, until their energy is damped out by radiation and other losses, as shown at *B*.

As the capacity and the inductance of the circuit, which may be made of any value, that is amount you wish, determine the *time period*, that is, the length of time for a current to make one complete oscillation, it must be clear that by varying the values of the condenser and the inductance coil you can make the high-frequency current oscillate as fast or as slow as you wish within certain limits. Where the electric oscillations that are set up are very fast, the waves sent out by the aerial will be short, and, conversely, where the oscillations are slow the waves emitted will be long.

CHAPTER V

HOW THE TRANSMITTING AND RECEIVING SETS WORK

THE easiest way to get a clear conception of how a radio transmitter sends out electric waves and how a receiving set picks them up is to take each one separately and follow: (1) in the case of the transmitter, the transformation of the low-voltage direct, or alternating current into high-potential alternating currents; then find out how these charge the condenser, how this is discharged by the spark gap and sets up high-frequency currents in the oscillation circuits; then (2) in the case of the receiver, to follow the high-frequency currents that are set up in the aerial wire and learn how they are transformed into oscillations of lower potential when they have a larger current strength, how these are converted into pulsating direct currents by the detector which then flow into and operate the telephone receiver.

How a Battery and Spark Coil Transmitting Set Works.—When you press down on the knob of the key the silver points of it make contact and this closes the circuit; the low-voltage direct current from the battery now flows through the primary coil of the spark coil and this magnetizes the soft iron core. The instant the core becomes magnetic it pulls the spring of the vibrator over to it and this breaks the circuit; when this takes place the current stops flow-

ing through the primary coil; this causes the core to lose its magnetism when the vibrator spring flies back and again makes contact with the adjusting screw; then the cycle of operations is repeated.

A condenser is connected across the contact points of the vibrator since this gives a much higher voltage at the ends of the secondary coil than where the coil is used without it; this is because: (1) the self-induction of the primary coil makes the pressure of the current rise and when the contact points close the circuit again it discharges through the primary coil, and (2) when the break takes place the current flows into the condenser instead of arcing across the contact points.

Changing the Primary Spark Coil Current into Secondary Currents.—Now every time the vibrator contact points close the primary circuit the electric current in the primary coil is changed into closed magnetic lines of force and as these cut through the secondary coil they set up in it a *momentary current* in one direction. Then the instant the vibrator points break apart, the primary circuit is opened and the closed magnetic lines of force contract, and as they do so they cut the turns of wire in the secondary coil in the opposite direction, and this sets up another momentary current in the secondary coil in the other direction. The result is that the low-voltage direct current of the battery is changed into alternating currents whose frequency is precisely that of the spring vibrator, but while the frequency of the currents is low, their potential, or voltage, is enormously increased.

What Ratio of Transformation Means.—To make a spark coil step up the low-voltage direct current into high-potential alternating current the primary coil is wound with a couple of layers of thick insulated copper wire, and the secondary is wound with a thousand, more or less, turns of very fine insulated copper wire. If the primary and secondary coils were wound with the same number of turns of wire, then the pressure, or voltage, of the secondary coil at its terminals would be the same as that of the current which flowed through the primary coil. Under these conditions the *ratio of transformation*, as it is called, would be unity.

The ratio of transformation is the proportion between the number of turns of wire on the secondary and primary coils, and since this is the case, if you wind 10 turns of wire on the primary coil and 1,000 turns of wire on the secondary coil, then you will get 100 times as high a pressure, or voltage, at the terminals of the secondary as that which you caused to flow through the primary coil, but, naturally, the current strength, or amperage, will be proportionately decreased.

The Secondary Spark Coil Circuit.—This includes the secondary coil and the spark gap which are connected together. When the alternating, but high potential currents which are developed by the secondary coil, reach the balls, or *electrodes* of the spark gap, the latter are alternately charged positively and negatively.

Now take a given instant when one electrode is charged positively and the other one is charged

negatively; when they are charged to a high enough potential the electric strain breaks down the air gap between them and the two charges rush together as described in the chapter before this one in connection with the discharge of a condenser. When the charges rush together they form a current which burns out the air in the gap and this gives rise to the spark, and as the heated gap between the two electrodes is a very good conductor the electric current surges forth and back with high frequency, perhaps a dozen times, before the air replaces that which has burned out. It is the inrushing air filling the vacuum of the gap that makes the crackling noise which accompanies the discharge of the electric spark.

In this way, then, electric oscillations of the order of a million, more or less, are produced, and if an aerial and a ground wire are connected to the spark balls, or electrodes, the oscillations will surge up and down it and the energy of these in turn are changed into electric waves which travel out into space. An open circuit transmitter of this kind will send out waves that are four times as long as the aerial itself, but as the waves it sends out are strongly damped the Government will not permit it to be used.

The Closed Oscillation Circuit.—By using a closed oscillation circuit the transmitter can be tuned to send out waves of a given length and while the waves are not so strongly damped more current can be sent into the aerial wire system. The closed oscillation circuit consists of: (1) a *spark gap*, (2) a *condenser* and (3) an *oscillation transformer*. The high-potential alternating current delivered by the

secondary coil not only charges the spark gap electrodes which necessarily have a very small capacity, but it charges the condenser which has a large capacity and the value of which can be changed at will.

Now when the condenser is fully charged it discharges through the spark gap and then the electric oscillations set up surge to and fro through the closed circuit. As a closed circuit is a very poor radiator of energy, that is, the electric oscillations are not freely converted into electric waves by it, they surge up to, and through the aerial wire; now as the aerial wire is a good radiator nearly all of the energy of the electric oscillations which surge through it is converted into electric waves.

How a Transmitting Set Works with Alternating Currents.—The operation of a transmitting set that uses an alternating-current transformer, or *power transformer*, as it is sometimes called, is even more simple than one using a spark coil. The alternations of the usual lighting current is 60 cycles per second. The transformer needs no vibrator when used with alternating current. The current from a generator flows through the primary coil of the transformer. This current sets up an alternating magnetic field in the core of the transformer, and as these magnetic lines of force expand and contract they set up alternating currents of the same frequency but of much higher voltage at the terminals of the secondary coil according to the ratio of the primary and secondary turns of wire, as explained under the sub-caption of *Ratio of Transformation*.

With Direct Current.—When a 110-volt direct current is used to energize the power transformer an *electrolytic* interrupter is needed to make and break the primary circuit, just as a vibrator is needed for the same purpose with a spark coil. When the electrodes are connected in series with the primary coil of a transformer and a source of direct current having a potential of 40 to 110 volts, bubbles of gas are formed on the end of the platinum, or alloy anode, which prevent the current from flowing until the bubbles break and then the current flows again. In this way the current is rapidly made and broken and the break is very sharp.

Where this type of interrupter is employed the condenser that is usually shunted around the break is not necessary as the interrupter itself has a certain inherent capacity, due to electrolytic action, which is called its *electrolytic capacity*, and this is large enough to balance the self-induction of the circuit since the greater the number of breaks per minute the smaller the capacity required.

The Rotary Spark Gap.—In this type of spark gap the two fixed electrodes are connected with the terminals of the secondary coil of the power transformer and also with the condenser and primary of the oscillation transformer. Now whenever any pair of electrodes on the rotating disk are in a line with the pair of fixed electrodes a spark will take place, hence the pitch of the note depends on the speed of the motor driving the disk. This kind of a rotary spark gap is called *non-synchronous*, and it is generally used where a 60-cycle alternating current

is available, but it will work with other higher frequencies.

The Quenched Spark Gap.—If you strike a piano string a single quick blow it will continue to vibrate according to its natural period. This is very much

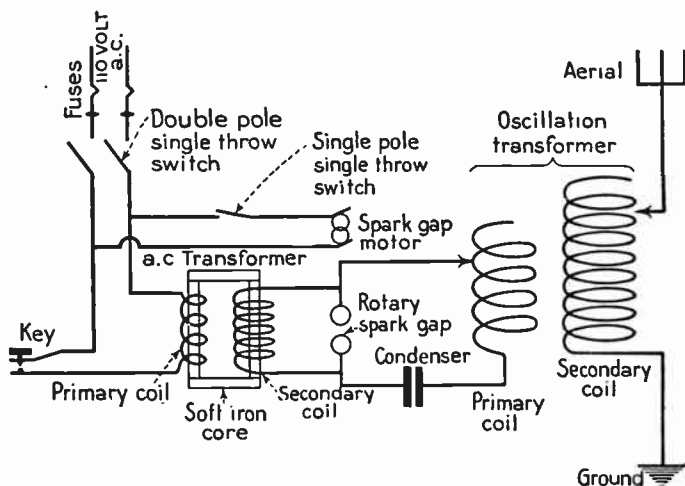


FIG. 28.—Wiring diagram for a transformer transmitter.

the way in which a quenched spark gap sets up oscillations in a coupled, closed, and open circuit. The oscillations set up in the primary circuit by a quenched spark make only three or four sharp swings and in so doing transfer all of their energy over to the secondary circuit, where it will oscillate some fifty times or more before it is damped out, because the high-frequency currents are not forced, but simply oscillate to the natural frequency of the circuit. For this reason the radiated waves approach

somewhat the condition of continuous waves, and so sharper tuning is possible.

The Oscillation Transformer.—In this set the condenser in the closed circuit is charged and discharged and sets up oscillations that surge through the closed circuit. Here, however, an oscillation transformer is used, and as its primary coil is included in the closed circuit the oscillations set up in it produce strong oscillating magnetic lines of force. The magnetic field thus produced sets up, in turn, electric oscillations in the secondary coil of the oscillation transformer, and these surge through the aerial wire system where their energy is radiated in the form of electric waves.

The great advantage of using an oscillation transformer instead of a simple inductance coil is that the capacity of the closed circuit can be very much larger than that of the aerial wire system. This permits more energy to be stored up by the condenser and this is impressed on the aerial when it is radiated as electric waves.

How the Tuning Coil Receiving Set Works.—When electric waves from a sending station impinge on the wire of a receiving aerial their energy is changed into electric oscillations that are of exactly the same frequency (assuming the receiver is tuned to the transmitter) but whose current strength (amperage) and potential (voltage) are very small. These electric waves surge through the closed circuit but when they reach the crystal detector the contact of the metal point on the crystal permits more current to flow through it in one direction than it

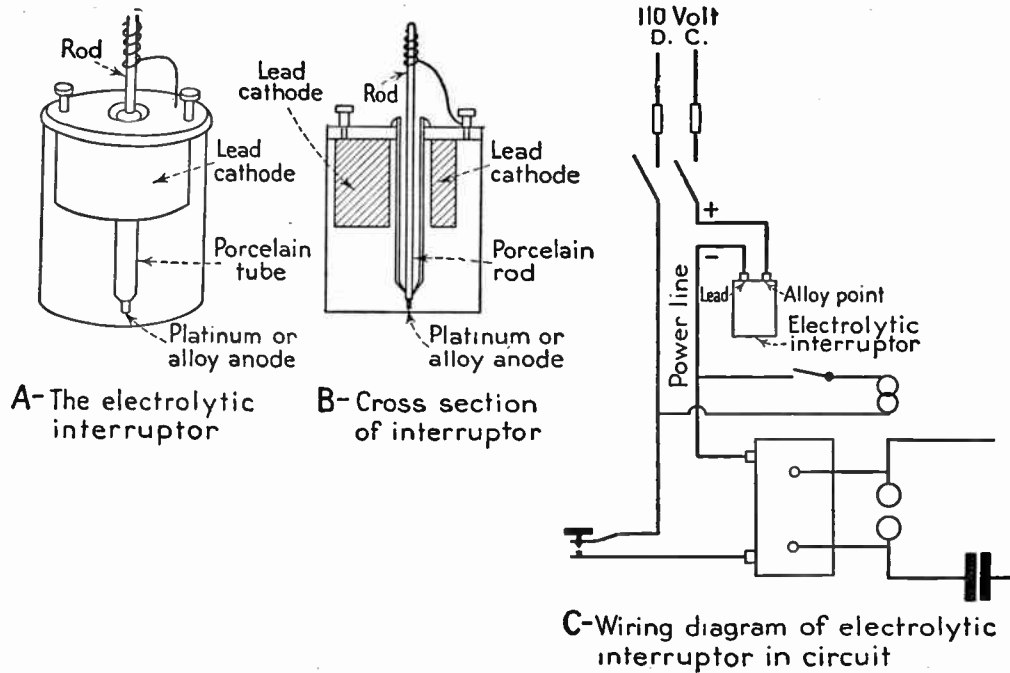


Fig. 29.—Using 110-volt d.c. with a transformer.

will allow to pass in the other direction. For this reason a crystal detector is sometimes called a *rectifier*, which it really is.

Thus the high-frequency currents which the steel magnet cores of the telephone receiver would choke off are changed by the detector into intermittent direct currents, which can flow through the magnet coils of the telephone receiver. Since the telephone receiver chokes off the oscillations, a small condenser can be shunted around it so that a complete closed oscillation circuit is formed and this gives better results.

When the intermittent rectified current flows through the coils of the telephone receiver it energizes the magnet as long as it lasts, when it is de-energized; this causes the soft iron disk, or *diaphragm* as it is called, which sets close to the ends of the poles of the magnet, to vibrate; and this in turn gives forth sounds such as dots and dashes, speech or music, according to the nature of the electric waves that sent them out at the distant station.

How the Loose Coupler Receiving Set Works.—When the electric oscillations that are set up by the incoming electric waves on the aerial wire surge through the primary coil of the oscillation transformer they produce a magnetic field, and as the lines of force of the latter cut the secondary coil, oscillations of the same frequency are set up in it. Since the secondary coil of the tuner and the condenser forms an oscillation circuit, the oscillations set up in it impress their voltage on the detector.

The oscillations then flow through the closed cir-

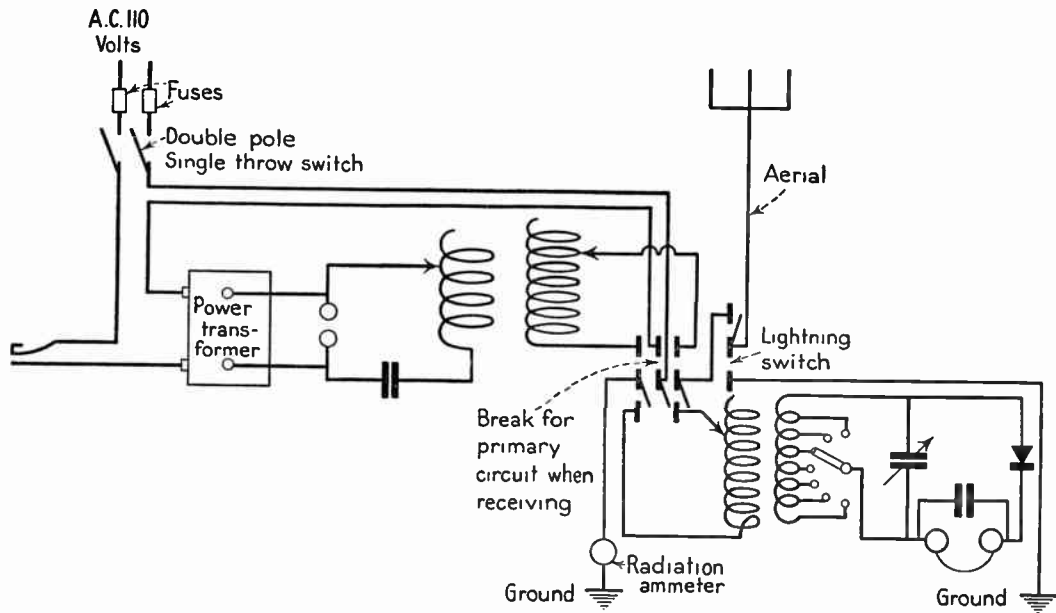


FIG. 30.—Wiring diagram of complete receiver and transmitter.

cuit where they are rectified by the crystal detector and transformed into sound waves by the telephone receiver as described in connection with the other set. The variable condenser shunted across the closed circuit permits finer secondary tuning to be done than is possible without it. Where you are receiving continuous waves from a radio telephone transmitter (speech or music) you have to tune sharper than is possible with the tuning coil alone and to do this a variable condenser connected in parallel with the secondary coil is necessary.

CHAPTER VI

MECHANICAL AND ELECTRICAL TUNING

THERE is a strikingly close resemblance between *sound waves* and the way they are set up in *the air* by a mechanically vibrating body, such as a steel spring or a tuning-fork, and *electric waves* and the way they are set up in *the ether* by a current oscillating in a circuit. As it is easy to grasp the way that sound waves are produced and behave, something will be told about them in this chapter and also an explanation of how electric waves are produced and behave, and thus you will be able to get a clear understanding of them and of tuning in general.

Damped and Sustained Mechanical Vibrations.— If you will place one end of a flat steel spring in a vice and screw it up tight as shown at *A* in *Fig. 31*, and then pull the free end over and let it go, it will vibrate to and fro with decreasing amplitude until it comes to rest as shown at *B*. When you pull the spring over you store up energy in it, this being called *potential* energy, and when you let it go, the stored-up energy is changed into energy of motion or *kinetic* energy and the spring moves forth and back, or *vibrates* as we call it, until all of its stored-up energy is spent.

If it were not for the air surrounding it and other frictional losses, the spring would vibrate for a very

long time as the stored-up energy and the energy of motion would practically offset each other and so the energy would not be used up. But as the spring beats the air, the latter is sent out in impulses and the conversion of the vibrations of the spring into waves

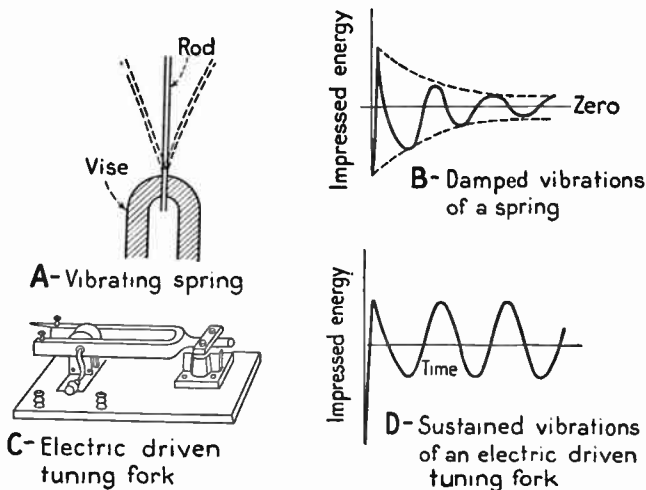


FIG. 31.—Illustrating damped and sustained mechanical vibrations.

in the air soon uses up the energy you have imparted to it and it comes to rest.

In order to send out *continuous waves* in the air instead of *damped waves* as with a flat steel spring, you can use an electrically-driven *tuning-fork*, see *C*, in which an electromagnet is fixed on the inside of the prongs and when this is energized by a battery current the vibrations of the prongs of the fork are kept going, or are *sustained*, as shown in the diagram at *D*.

Damped and Sustained Electric Oscillations.—The vibrating steel spring described above is a very

good analogue of the way that damped electric oscillations which surge in a circuit set up and send out periodic electric waves in the ether, while the electrically-driven tuning-fork, just described, is likewise a good analogue of how sustained oscillations surge

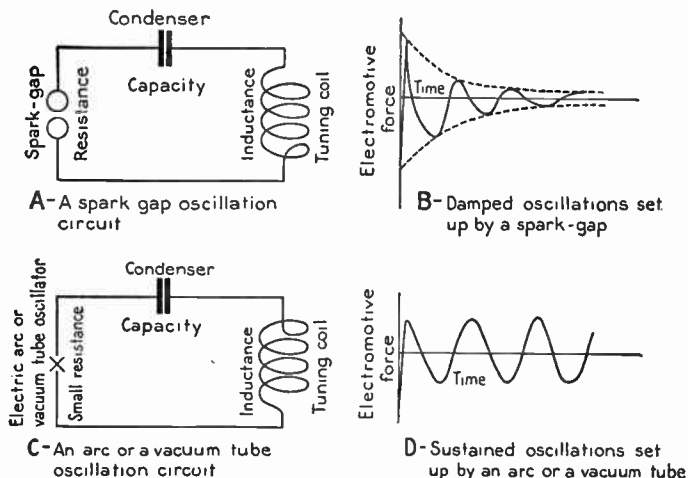


FIG. 32.—Damped and sustained electrical vibrations.

in a circuit, and set up and send out continuous electric waves in the ether, as the following shows.

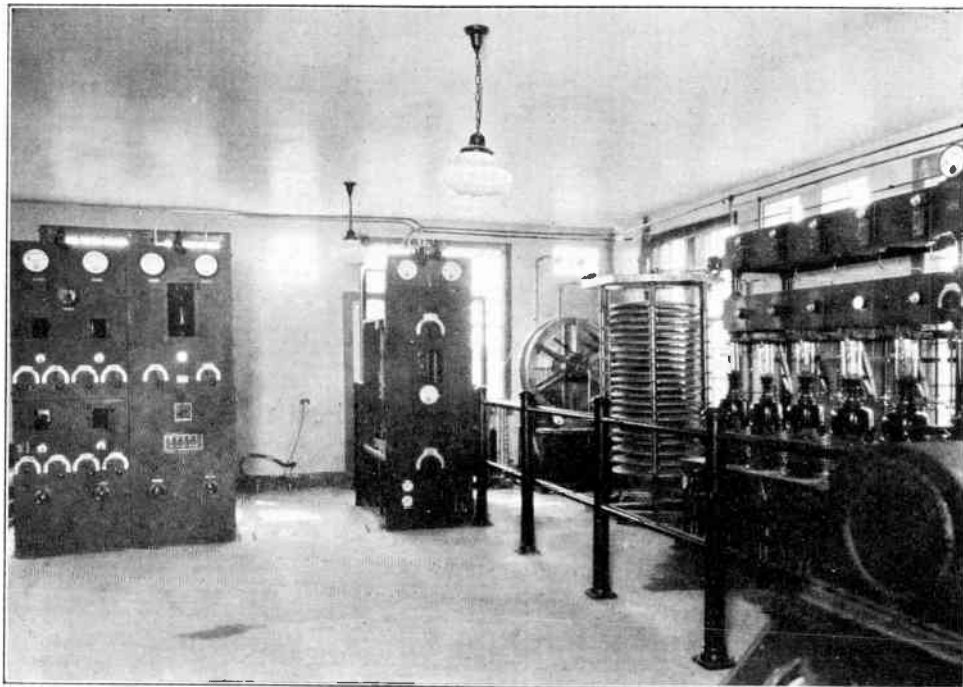
Now the inductance and resistance of a circuit such as is shown at *A* in *Fig. 32*, slows down, and finally damps out entirely, the electric oscillations of the high-frequency currents, see *B*, where these are set up by the periodic discharge of a condenser, precisely as the vibrations of the spring are damped out by the friction of the air and other resistances that act upon it. As the electric oscillations surge to and fro in the circuit it is opposed by the action of the ether

which surrounds it and electric waves are set up in and sent out through it and this transformation soon uses up the energy of the current that flows in the circuit.

To send out *continuous waves* in the ether such as are needed for radio telephony, instead of *damped waves* an *electric oscillation arc* or a *vacuum tube oscillator* must be used, see *C*, instead of a spark gap. Where a spark gap is used, the condenser in the circuit is charged periodically and with considerable lapses of time between each of the charging processes, when, of course, the condenser discharges periodically and with the same time element between them. Where an oscillation arc or a vacuum tube is used, the condenser is charged as rapidly as it is discharged, and the result is the oscillations are sustained as shown at *D*.

About Mechanical Tuning.—A tuning-fork is better than a spring or a straight steel bar for setting up mechanical vibrations. As a matter of fact, a tuning-fork is simply a steel bar bent in the middle so that the two ends are parallel. A handle is attached to middle point of the fork so that it can be held easily and allow it to vibrate freely, when the ends of the prongs alternately approach and recede from one another. When the prongs vibrate, the handle vibrates up and down in unison with it, and imparts its motion to the *sounding box*, or *resonance case* as it is sometimes called, where one is used.

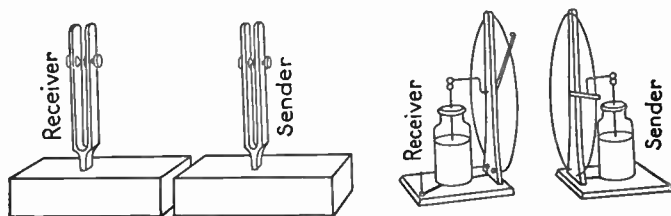
If, now, you will mount the fork on a sounding box, which is constructed so that it will be in resonance with the vibrations of the fork, there will be a direct reinforcement of the vibrations when the note emitted by it will be augmented in strength and



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The five stages of radio frequency in the W.E.A.F. transmitter at Bellmore, L. I. On the extreme left is the crystal-control apparatus for holding the station to a constant frequency of 610 kilocycles.

quality. This is called *simple resonance*. Further, if you mount a pair of forks, each on a separate sounding box, and have the forks of the same size, tone and pitch, and the boxes *synchronized*, that is, tuned to the same frequency of vibration, then set the two boxes a foot or so apart, as shown at *A* in *Fig. 33*, when you strike one of the forks with a rubber



A-Variable tuning forks for showing sound wave tuning

B-Variable oscillation circuits for showing electric wave tuning

FIG. 33.—Sound wave and electrical wave tuned transmitters and receivers.

hammer it will vibrate with a definite frequency and, hence, send out sound waves of a given length. When the latter strike the second fork the impact of the molecules of air of which the sound waves are formed will set its prongs to vibrating and it will, in turn, emit sound waves of the same length and this is called *sympathetic resonance*, or as we would say in radio the forks are *in tune*.

Tuning-forks are made with adjustable weights on their prongs, and by fixing these to different parts of them the frequency with which the forks vibrate can be changed, since the frequency varies inversely with the square of the length and directly with the

thickness ¹ of the prongs. Now by adjusting one of the forks so that it vibrates at a frequency of, say, 16 per second and adjusting the other fork so that it vibrates at a frequency of, say, 18 or 20 per second, then the forks will not be in tune with each other and, hence, if you strike one of them the other will not respond. But if you make the forks vibrate at the same frequency, say 16, 20 or 24 per second, when you strike one of them the other will vibrate in unison with it.

About Electric Tuning.—Electric resonance and electric tuning are very like those of acoustic resonance and acoustic tuning which has just been described. Just as acoustic resonance may be simple or sympathetic so electric resonance may be simple or sympathetic. *Simple acoustic resonance* is the direct reinforcement of a simple vibration and this condition is had when a tuning-fork is mounted on a sounding box. In simple electric resonance an oscillating current of a given frequency flowing in a circuit having the proper inductance and capacity may increase the voltage until it is several times greater than its normal value. Tuning the receiver circuits to the transmitter circuits are examples of sympathetic electric resonance. As a demonstration, if you have two Leyden jars (capacity) connected in circuit with two loops of wire (inductance) whose inductance can be varied as shown at *B* in *Fig. 33*, when you make a spark pass between the knobs of one of them by means of a spark coil then a spark will pass in the gap of the other one provided

¹ This law is for forks having a rectangular cross-section. Those having a round cross-section vary as the radius.

the inductance of the two loops of wire is the same. But if you vary the inductance of the one loop so that it is larger or smaller than that of the other loop no spark will take place in the second circuit.

When a tuning-fork is made to vibrate it sends out waves in the air, or sound waves, in all directions and just so when high-frequency currents surge in an oscillation circuit they send out waves in the ether, or electric waves, that travel in all directions. For this reason electric waves from a transmitting station cannot be sent to one particular station, though they do go further in one direction than in another, according to the way the aerial wire points.

Since electric waves travel out in all directions, any receiving set properly tuned to the wavelength of the transmitting station will receive the waves, and the only limit on your ability to receive from high-power stations throughout the world depends entirely on the wavelength and sensitivity of your receiving set. As for tuning, just as changing the length and the thickness of the prongs of a tuning-fork varies the frequency with which it vibrates and, hence, the length of the waves it sends out, so, too, by varying the capacity of the condenser and the inductance of the tuning coil of the transmitter the frequency of the electric oscillations set up in the circuit may be changed and, consequently, the length of the electric waves they send out. Likewise, by varying the capacity and the inductance of the receiver the circuits can be tuned to receive incoming electric waves of whatever length within the limitation of the apparatus.

CHAPTER VII

A SIMPLE VACUUM TUBE DETECTOR RECEIVING SET

WHILE you can receive dots and dashes from spark radio telegraph stations, and hear spoken words and music from radio telephone stations with a crystal detector receiving set such as described in *Chapter III*, you can get stations that are much farther away and hear them better with a *vacuum tube detector* receiving set.

Though the vacuum tube detector requires two batteries to operate it, and the receiving circuits are somewhat more complicated than where a crystal detector is used still the former does not have to be constantly adjusted as does the latter and this is another very great advantage. Taken all in all, the vacuum tube detector is the most sensitive and the most satisfactory of the detectors that are in use at the present time.

Not only is the vacuum tube a detector of electric wave signals and speech and music but it can also be used to *amplify* them, that is, to make them stronger and, hence, louder in the telephone receiver. Its powers of amplification are so great that it will reproduce them by means of a *loud speaker*, just as a horn amplifies the sounds of a phonograph reproducer, until they can be heard by a room or an

A Vacuum Tube Detector Receiving Set 71

auditorium full of people. There are two general types of loud speakers, though both use the principle of the telephone receiver. The construction of these loud speakers will be fully described in a later chapter.

Assembled Vacuum Tube Receiving Sets.—You can buy a receiving set with a vacuum tube detector from the very simplest type, which is described in this chapter, to those that are provided with *regenerative circuits* and *amplifying tubes* or both, which we shall describe in later chapters, from dealers in electrical apparatus generally. While one of these sets costs more than if you assembled a set for yourself, still, especially in the beginning, it is a good plan to buy an assembled one for it is fitted with a *panel* on which the adjusting knobs of the rheostat, tuning coil and condenser are mounted, and this makes it possible to operate it as soon as you get it home and without the slightest trouble on your part.

You can, however, buy all the various parts separately and mount them yourself. If you want the receiver simply for picking up signals, then it is a good scheme to have all of the parts mounted in a box or enclosed case, but if you want it for experimental purposes, then the parts should be mounted on a base or a panel so that all of the connections are in sight and accessible.

The Vacuum Tube Detector. With Two Electrodes.—A vacuum tube in its simplest form consists of a glass bulb like an incandescent lamp in which a *wire filament* and a *metal plate* are sealed, as shown in *Fig. 34*. The air is then pumped out

of the tube and a vacuum left, or after it is exhausted it is filled with nitrogen, which cannot burn.

When the vacuum tube is used as a detector, the wire filament is heated red-hot and the metal plate is charged with positive electricity, though it remains cold. The wire filament is formed into a loop like that of an incandescent lamp and its outside ends are connected with a filament heating battery, which

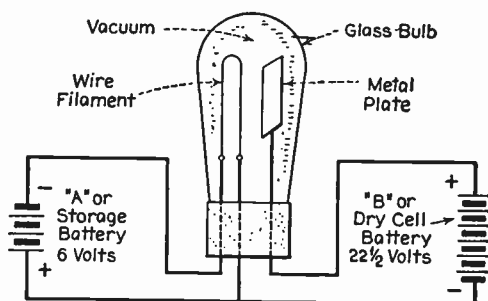


FIG. 34.—How a two-electrode vacuum tube is connected.

is called the *A* battery; then the + or *positive* terminal of a 22½-volt dry cell battery, called the *B* battery, is connected to the metal plate, while the - or *negative* terminal of the battery is connected to one of the terminals of the wire filament. The diagram, *Fig. 34*, simply shows how the two electrode vacuum tube, the *A* battery, and the *B* battery are connected up. This type of tube is now obsolete, having been supplanted by the three-electrode type.

Three-Electrode Vacuum Tube Detector.—The three-electrode vacuum tube detector shown at *A* in *Fig. 35*, is much more sensitive than the two-electrode tube. In this more recent type of vacuum tube the

A Vacuum Tube Detector Receiving Set 73

third electrode, or *grid*, as it is called, is placed between the wire filament and the metal plate and this allows the current to be increased or decreased at will to a very considerable extent.

At the present time there are numerous types of three-electrode vacuum tubes on the market and it is for the reader to decide what ones he wishes to use.

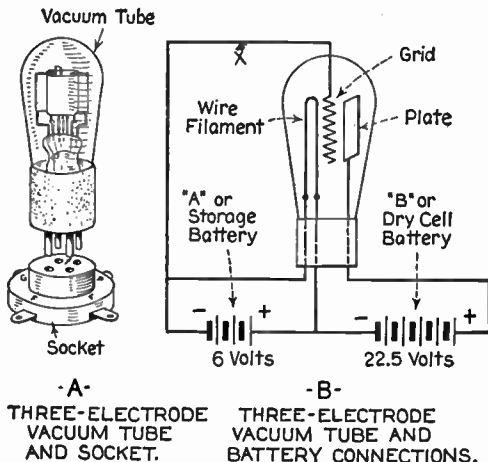


FIG. 35.—Three-electrode vacuum tube and its connections.

Some are designed for use as detectors, some as amplifiers and others are adapted to both uses.

Their sub-division is what is of most importance, as you may be so situated that the use of a storage battery would be out of the question. In such a case it would be necessary to use dry cells to light the filament of the vacuum tube. Now the large 6-volt tubes draw a large amount of current and dry cells would be quickly drained. The small 4-volt tubes however draw very little current and

therefore dry cells are satisfactory. Three dry cells connected in series will light from one to three UV-199 vacuum tubes for a long period of time before becoming exhausted.

The various types of vacuum tubes you can use are explained in the vacuum tube chart in the back

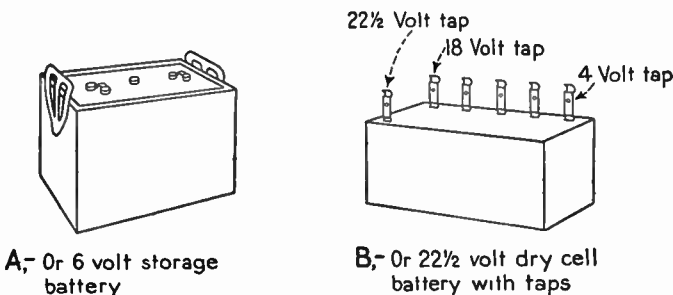


FIG. 36.—Batteries for vacuum tubes.

of the book and will tell you what kind of *A* or filament-heating battery must be used with each.

The way the three-electrode vacuum tube detector is connected with the batteries is shown at *B*. The plate, the *B* or dry cell battery and one terminal of the filament are connected in *series*—that is, one after the other, and the ends of the filament are connected to the *A* or filament heating battery. In assembling a receiving set you must, of course, have a socket for the vacuum tube.

The Filament Heating and Plate Batteries.—The filament heating or *A* battery, as mentioned previously, can be one of two types; a storage battery as shown in *A* of *Fig. 36* or one or more $1\frac{1}{2}$ -volt dry cells of the kind shown in *A* of *Fig. 3*. The *B* or

dry cell battery for the vacuum tube plate circuit that gives $22\frac{1}{2}$ volts comes already assembled in sealed boxes. The small size is fitted with a pair of terminals while the larger size is provided with *taps* so that the voltage required by the plate can be adjusted, as the proper operation of the tube

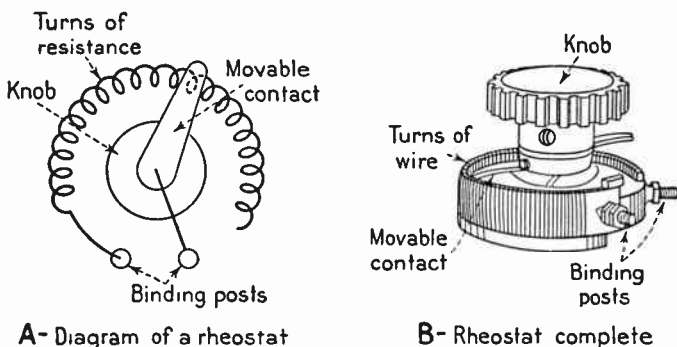


FIG. 37.—Rheostat for filament control.

requires careful regulation of the plate voltage. A dry cell battery for a plate circuit is shown at *B*.

The Filament Rheostat.—An adjustable resistance, called a *rheostat*, must be used in the filament and *A* battery circuit so that the current flowing through the filament can be controlled to a nicety. The rheostat consists of an insulating and a heat resisting form on which is wound a number of turns of resistance wire. A movable contact arm that slides over and presses on the turns of wire is fixed to the knob on top of the rheostat. The resistance of the rheostat depends upon the type of vacuum tube with which it is designed to be used. A popular type of rheostat is shown at *A* and *B* of *Fig. 37*.

A Simple Vacuum Tube Receiving Set.—For this set you should use:

- 2 .00025 mf. variable condensers, C1 and C2
- 1 55 mmf. variable condenser, C3
- 1 .0005 mf. fixed condenser, C4, with grid leak mounting
- 1 7 megohm grid leak, R1
- 1 6-ohm rheostat, R2
- 1 UX-type socket
- No. 16 D. C. C. wire for coils
- 11 binding posts
- 1 "A" battery
- 1 "B" battery of 22½ volts

Assembling the Parts.—If this is the constructor's first radio receiver it is advised that he lay out the apparatus and connect it up on a baseboard, for which purpose a cheap breadboard will do very well.

First mount about 4 inches apart the two larger variable condensers, C1 and C2 in *Fig. 38*, near the front of the board so that they may be varied without your hands coming near the other apparatus. Then nearer to the middle of the board and behind the condensers mount six of the binding posts about an inch apart, these being for the coils. Number these posts from 1 to 6 inclusive. Near the left-hand post which you have marked No. 1 mount the grid condenser, C4 and close to this with the "Grid" terminal next to it, mount the vacuum tube socket. (It is always good practice to have grid leads as short as possible.) The small midget condenser of 55 mmf., C3, is then mounted near the binding posts Nos. 5 and 6 and in line with C1 and C2. The rheostat, R2, is then mounted near the negative terminal of the

post No. 1 to the grid terminal of the socket. The positive terminal of the socket is connected to one of the battery binding posts, which is then marked, "Plus A, Minus B and Ground." One terminal of the rheostat is connected to the negative terminal of the socket and the other side is connected to another battery terminal and this is marked "Minus A." Connect the Plate terminal of the socket to the nearest binding post of the pair for phones, the second one being connected to the third battery binding post, which is then marked "Plus 22½ B."

Winding the Coils.—In order to listen-in on the various signals that are being sent out on different wavelengths it is necessary to have a set of coils for each particular band of wavelengths. These coils, marked L1, L2, L3 and L4 in the diagram are very easily wound from No. 16 D. C. C. wire and can be completed in a relatively short time.

Following will be found the number of turns necessary for each band of wavelengths.

| Wavelength | Coils | L1 | L2 | L3 | L4 |
|----------------|-------|----|----|----|----|
| 20-meter band | | 4 | 2 | 2 | — |
| 40-meter band | | 8 | 4 | 4 | — |
| 80-meter band | | 16 | 8 | 8 | 4 |
| 150-200 meters | | 16 | 16 | 8 | 8 |
| 200-500 meters | | 32 | 16 | 8 | 8 |

The coils are not wound on any permanent form and they are "bunch wound," which means that after the correct number of turns have been wound on a form about 3 inches in diameter, the turns are carefully slipped off and fastened together at

A Vacuum Tube Detector Receiving Set 79

the bottom, where there are several inches left for the leads, with a strip of tape. These leads are the means of mounting the coils and connecting them to the proper binding posts. In every case after coils L1, L2 and L3 have been wound they can be fastened together with tape after their leads have been connected to the proper binding posts. The coil, L4, is kept separate, the leads of this being connected to posts Nos. 5 and 6. To make matters easier in changing coils, the leads of coils L1 and L2 that go to post No. 2 may be twisted together and the same may be done with the leads of L2 and L3 that go to post No. 3.

It will be noted that there is no coil, L4, for the 20- and 40-meter wave bands. In this case the midget condenser is connected in series with the antenna, when nothing is connected to the binding posts 5 and 6, this having the effect of shortening the length of the antenna, so that one used for broadcasts reception may be used on the short waves.

Be sure to tape the coils together securely at their bottom, so that there is no danger of their coming undone. The turns of wire at the coils' tops may be spread out a bit; to do so might improve reception.

Operation.—Place the grid leak in its mountings on the condenser, C4. Connect the antenna to the binding post No. 6 and your ground to the terminal so marked.

Next connect your *A* battery to the binding posts which have been marked "Plus and Minus *A*," being careful that the positive side of the battery is connected to its proper post on the board. It de-

depends, of course, upon what type of a tube you are using whether or not you need a storage battery. We will assume that you are using a 201-A tube, which does need one to properly light its filament. The binding posts of such a battery are always plainly marked as to their polarity.

If you now insert your vacuum tube in the socket, being careful to see that it is properly positioned before firmly thrusting it into the socket, the filament should light when you rotate the arm of the rheostat. It is unnecessary to have the filament lit very brilliantly; keep it lit dimly. If the filament does not light, there is some mistake in the wiring and you should go over your work and check it thoroughly.

Now place a tip in each of the two binding posts marked "Phones" of your headset. Then connect your *B* battery to its proper binding posts, being careful again to get the correct terminals connected to the proper binding posts.

A set of the coils that you have wound are then chosen. To test the set most quickly it is suggested that you first use the "200-500 meters" coils, which will give you signals from the broadcast stations. After these have been connected to their proper binding posts, you are ready to listen-in.

Tuning the Receiver.—After you have checked all connections, lit the filament of the tube, with the phones on your ears, *slowly* vary the tuning condenser C1. When a signal is heard turn it a bit more until it becomes loudest and then try to get it even louder by varying the midget condenser, C3. If

there is a series of whistles in the set when you are varying C1, clear them up by using C2.

As this set can be annoying to one's radio neighbors if it is continually whistling or oscillating, keep C2 so that it is always just under this point of breaking into oscillation. A little practice will tell you where this point is and this is the most efficient point upon which to listen to a station.

Adjusting the Vacuum Tube Detector Receiving Set.—The sensitivity of the vacuum tube detector receiving set and, hence, the distance over which signals and other sounds can be heard, depends very largely on the sensitivity of the vacuum tube itself and this in turn depends on: (1) the right amount of heat developed by the filament, or *filament brilliancy* as it is called, (2) the right amount of voltage applied to the plate, and (3) the extent to which the tube is exhausted where this kind of a tube is used.

To vary the current flowing from the *A* battery through the filament so that it will be heated to the right degree you adjust the rheostat while you are listening-in to the signals or other sounds. By carefully adjusting the rheostat you can easily find the point at which it makes the tube the most sensitive. A rheostat is also useful in that it keeps the filament from burning out when the current from the battery first flows through it.

When the sensitiveness of the vacuum tube starts to decrease, the storage battery should be recharged or the dry cells renewed as the case may be. Furthermore, when crackling noises are heard in the headphones it is time to purchase new dry cell *B* batteries.

The degree to which a vacuum tube has been exhausted has a very pronounced effect on its sensitivity. The longer a gas tube is used the higher its vacuum gets and generally the less sensitive it becomes. Vacuum tubes having a gas content (in which case they are, of course, no longer vacuum tubes in the strict sense) make better detectors than tubes from which the air has been exhausted and which are sealed off in this evacuated condition, because their sensitiveness is not dependent on the degree of vacuum as in the latter tubes.

CHAPTER VIII

VACUUM TUBE AMPLIFIER RECEIVING SETS

THE reason a vacuum tube detector is more sensitive than a crystal detector is because while the latter merely *rectifies* the oscillating current that surges in the receiving circuits, the former acts as an *amplifier* at the same time. The vacuum tube can be used as a separate amplifier in connection with either: (1) a *crystal detector* or (2) a *vacuum tube detector*, and (a) it will amplify either the *radio-frequency currents*, that is the high-frequency oscillating currents which are set up in the oscillation circuits or (b) it will amplify the *audio-frequency currents*, that is, the *low-frequency* currents that flow through the phone circuit.

To use the amplified radio-frequency oscillating currents or amplified audio-frequency currents that are set up by an amplifier tube, either a high resistance, such as a *grid leak*, or an *amplifying transformer*, with or without an iron core, must be connected with the plate circuit of the first amplifier tube and the grid circuit of the next amplifier tube or detector tube, or with the wire point of a crystal detector. Where two or more amplifier tubes are coupled together in this way the scheme is known as *cascade amplification*.

The Vacuum Tube Amplifier.—This consists of a three-electrode vacuum tube exactly like the vacuum

tube detector described in *Chapter VII*, except that instead of being filled with a non-combustible gas it is evacuated; that is, the air has been completely pumped out of it. The gas filled tube, however, can be used as an amplifier and either kind of tube can be used for either radio-frequency or audio-frequency amplification, though with the exhausted tube it is easier to obtain the right plate and filament voltages for good working.

The vacuum tube chart in the back of the book will tell you what tubes are best adapted to this purpose.

A Tuned Radio-Frequency Receiver.—There are a great many variations of this type of circuit and the majority of the higher-priced receivers employ it, as it is excellent for distant reception as well as volume of reproduction. It will be noticed that there is a similarity between the circuit in *Fig. 39* and the Neutrodyne shown in *Fig. 41*, the main difference being in the addition of a 400-ohm potentiometer, which replaces the neutralizing condensers.

In tuning this receiver, the three variable 23 plate condensers are placed at approximately the same dial readings. When a station is heard the quality of reception can be brought to maximum by varying the potentiometer, which varies the grid bias of the first two tubes. The volume of the loud speaker can be regulated by changing the filament rheostat of the last two tubes.

The Parts and How to Connect Them.—You will require (1) 3 radio-frequency transformers; (2) 3 23 plate variable condensers (.0005 mfd.), preferably

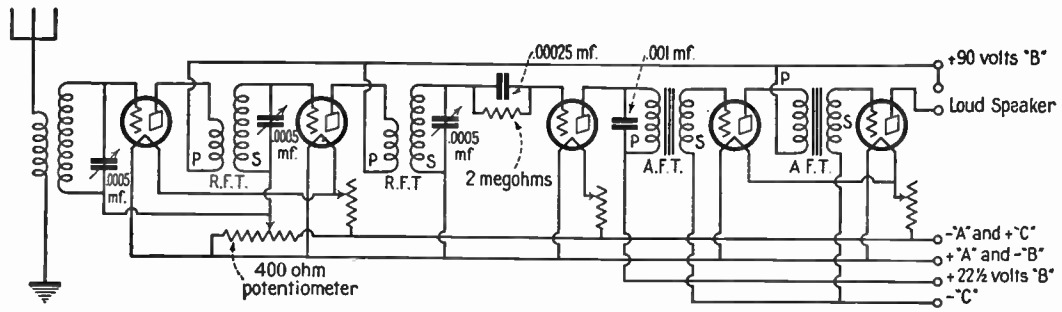


FIG. 39.—Tuned Radio-Frequency Receiver.

of the straight line frequency type; (3) 2 fixed condensers (.00025 mfd.), and (.001 mfd.); (4) a grid leak, 2 megohms; (5) 4 amplifier vacuum tubes; (6) 1 detector vacuum tube; (7) 5 tube sockets; (8) a potentiometer, 400 ohms; (9) 3 filament rheostats; (10) 2 audio-frequency transformers, ratios of 5 to 1 and 3 to 1; (11) an "A" battery; (12) a "B" battery capable of delivering 90 volts; (13) a "C" battery of 4½ volts; (14) a pair of headphones or loud speaker.

The radio-frequency transformers can be wound by the constructor. Procure sufficient hard rubber or bakelite tubing, 3 inches in diameter, for the three transformers and a ¼ lb. of No. 22 B. & S. gauge D. C. C. wire. The secondary winding consists of fifty turns of the wire and the primary, which is wound over the secondary and in the same direction, has ten turns. The ends of the coils should be securely fastened to the tubing. *Fig. 39* shows the diagram of connections. If the oscillations, or howls, cannot be eliminated completely by means of the potentiometer, try reversing the leads to the radio-frequency transformers.

A *radio-frequency transformer* is made like a loose coupled tuning coil. See *Fig. 40*. The high-frequency, or *radio-frequency* oscillation currents, as they are called, surge through the amplifiers and are not changed into low-frequency, or *audio-frequency* pulsating currents, until they flow through the detector.

A Neutrodyne Receiver.—The *Neutrodyne* circuit was invented by Professor L. A. Hazeltine of Stevens

Institute of Technology. It is a very sensitive form of radio-frequency amplifier and is a decided improvement over the usual type. As explained, it is necessary to use a *potentiometer* with a radio-frequency amplifier to stabilize the circuit, that is to prevent it from oscillating. The very means by which it is prevented represents a considerable loss of energy that cannot be made up for. In other words it is

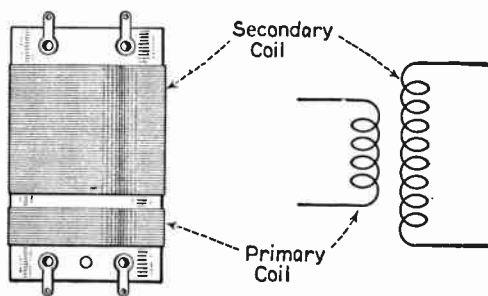


FIG. 40.—A radio-frequency transformer.

essential that an amount of amplification be sacrificed in order that we may receive broadcast programs that are free from distortion.

The Neutrodyne kills two birds with one stone. First, small condensers called *neutralizing condensers* are employed to neutralize the *inter-element* capacity of the vacuum tubes which is the cause of the circuit oscillating. This eliminates the potentiometer and its accompanying losses. Second, since the circuit cannot oscillate after once being neutralized, advantage is taken of *tuned-plate radio-frequency amplification*, which is a much more sensitive system than the transformer type but too critical to use effectively in

a circuit where a potentiometer is the only means for controlling oscillation. This type of transformer is called a *Neutroformer* and is tuned by means of a variable condenser connected across its secondary winding. Unlike the now obsolete type of radio-frequency transformer, the *Neutroformer* has no iron core. In this three-tube Neutrodyne set there are three variable condensers and they are the only controls. The first two tubes serve as radio-frequency amplifiers and the third as a detector. The *regenerative* feature, which will be described fully in a later chapter, may be added by placing a variometer in the plate circuit of the detector vacuum tube as shown in the diagram of *Fig. 41*, but instead of this two stages of audio-frequency amplification may be used to greater advantage.

Although it is possible to construct the Neutroformers and the neutralizing condensers it is advised that they be purchased, as little mistakes are apt to cause no end of trouble. Radio dealers carry complete parts for these sets which makes their construction easy.

The Parts and How to Connect Them Up.—You will need (1) three Neutroformers; (2) three 23 plate variable condensers (these are usually parts of the Neutroformers); (3) one .0005 mfd. fixed condenser; (4) one .00025 mfd. fixed grid condenser; (5) a grid leak; (6) two neutralizing condensers; (7) two amplifier vacuum tubes; (8) one detector vacuum tube; (9) three tube sockets; (10) three 22½-volt *B* batteries; (11) an *A* battery; (12) three rheostats; (13) a variometer if you wish *regeneration*; (14) a pair of headphones or loud speaker.

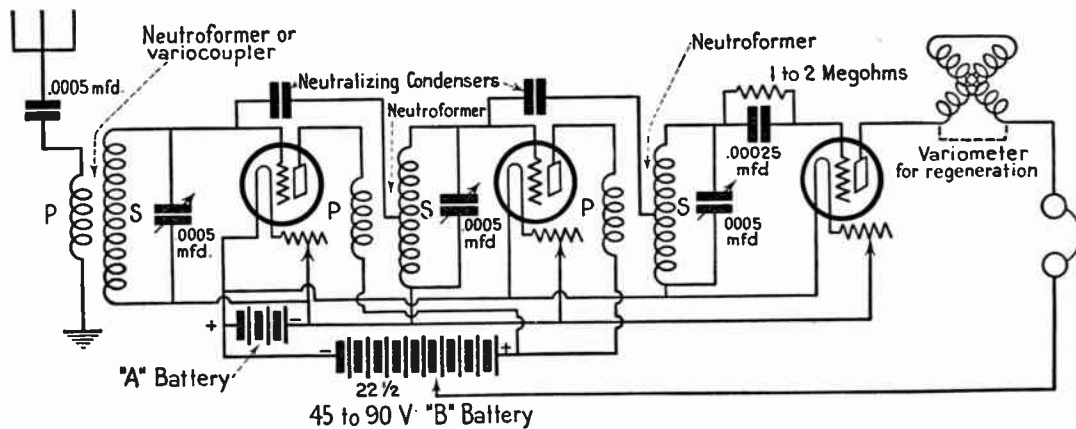


FIG. 41.—Circuit diagram of Neutrodyne receiver, using three tubes.

The circuit of *Fig. 41* shows how the instruments are connected up. If you do not wish regeneration the variometer is eliminated and the circuit continued as shown by the dotted line.

A Superheterodyne Receiver.—This is the most sensitive type of short-wave radio-receiver in existence to-day and is another of Major Edwin H. Armstrong's contributions to the radio field. Although at least six vacuum tubes are required, the control of this receiver is quite simple. Two variable condensers are provided for this purpose.

The first vacuum tube in this set functions as an *oscillator* and together with its own circuit is known as the *external heterodyne*. The second tube is the *first* detector or *frequency changer*, the third, fourth and fifth tubes are the radio-frequency amplifiers, and the sixth vacuum tube is the *second* detector.

The radio-frequency transformers for this set are designed to amplify signals at a wavelength of from 5,000 to 25,000 meters instead of at the true wavelength of the signal, which in our case is from 220 to 550 meters, the broadcast waves. Just how this is done is described in *Chapter XVIII* which you should read before attempting the construction of one of these sets.

The *oscillator coil unit*, which is a part of the *external heterodyne*, is constructed as follows: On a cardboard tube 3 inches in diameter, starting at the left end, wind 8 turns of No. 20 D. C. C. copper wire. This forms coil *A* as shown in the diagram. Starting 2 inches from the end of coil *A* wind 20 turns of the same size wire. This is coil *B*. About $\frac{3}{4}$ inch from

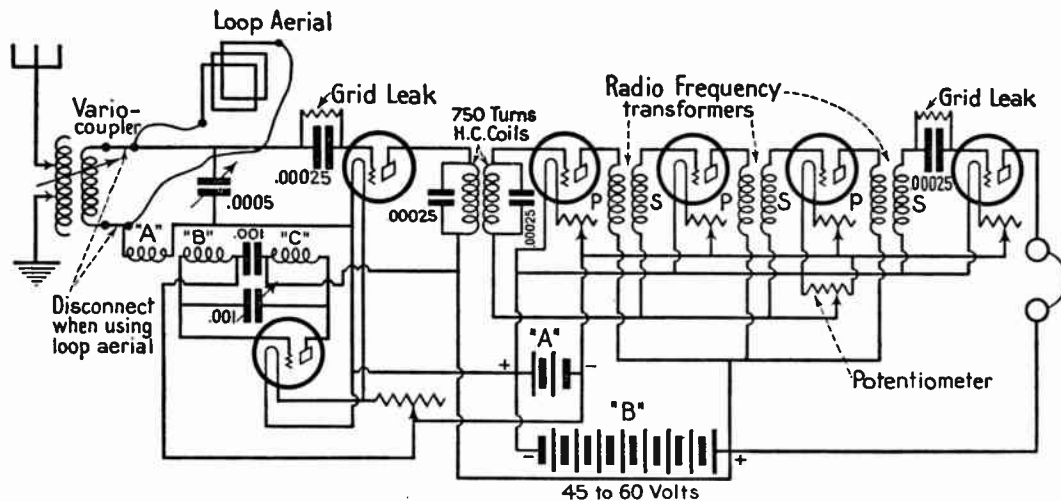


FIG. 42.—Wiring diagram of a Superheterodyne receiver, with which may be used either an outdoor or indoor aerial.

the end of coil *B* wind 35 turns of the same size wire. This forms coil *C* and completes the unit.

The two 750-turn honeycomb coils really make up another radio-frequency transformer, but they are used so as to provide coupling and so make the circuit more selective. The correct coupling is had when the received signals are the loudest. When the coupling is once found the coils need not be touched again.

The Parts and How to Connect Them Up.—You will need the following parts for building the Superheterodyne receiver: (1) a variocoupler; (2) a 23 plate (.0005 mfd.) variable condenser; (3) a 43 plate (.001 mfd.) variable condenser; (4) a .001 mfd. fixed condenser; (5) four .00025 mfd. fixed condensers; (6) two 750-turn honeycomb coils; (7) three long-wave radio-frequency amplifying transformers; (8) ½ pound of copper wire and a cardboard tube for constructing the oscillator coil unit; (9) two 2 megohm grid leaks; (10) five 30-ohm rheostats; (11) a 400-ohm potentiometer; (12) an *A* battery; (13) three 22½-volt *B* batteries; (14) six UV-199 or UV-201-A vacuum tubes; (15) six vacuum tube sockets; (16) a pair of headphones or a loud speaker.

The circuit diagram of *Fig. 42* shows how the different instruments are connected up. Included in this diagram are connections showing how a loop aerial can be employed in place of the aerial and ground if desirable. If you wish more volume than this receiver gives, the two-step audio-frequency amplifier described in this chapter and shown in *Fig. 50* can be added by taking out the headphones in the Superheterodyne circuit and connecting the

two *primary* terminals of the first audio-frequency transformer to where the headphones were attached. A loud speaker is then connected to the *output* terminals of the amplifier.

An Audio-Frequency Transformer Amplifying Receiving Set.—Where audio-frequency transformers are used for stepping up the voltage of the current of the detector and amplifier tubes, the radio-frequency current does not get into the plate circuit of the detector at all, for the reason that the iron core of the transformer chokes them off, hence, the succeeding amplifiers operate at audio frequencies.

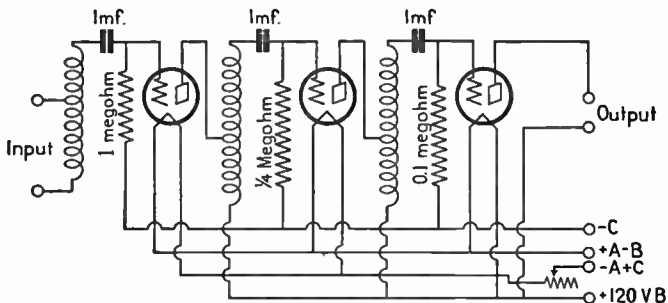
Audio-Frequency Amplifiers.—This type of amplification can be divided into four groups, as follows:

- a. Transformer coupled.
- b. Impedance coupled.
- c. Resistance coupled.
- d. Pushpull.

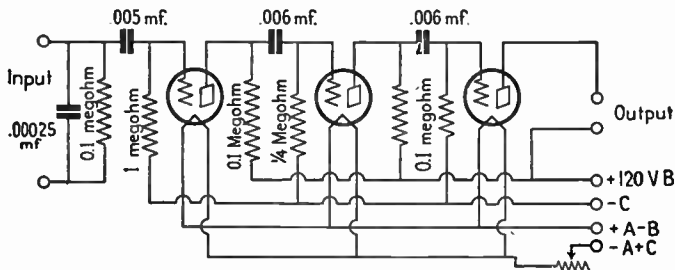
Each of these four styles of amplification has its own advantages and disadvantages. The first one mentioned, transformer coupled, is the one that is most frequently used, as the cost is relatively low for the necessary apparatus and the results are generally satisfactory.

The second type, impedance coupled, uses an auto-transformer, a high capacity condenser and a resistor in each stage. The advantage of this type of coupling is that a higher plate voltage may be used on the amplifying tubes, which results in greater volume. However this type is more or less subject to the dis-

advantages of transformer coupling, because of the difficulties experienced in the construction of transformers that will have a uniform distortionless range. Another drawback is that as the tubes alone



A- Impedance coupled A F Amplifier



B-Resistance coupled A F Amplifier

FIG. 43.—Two types of audio-frequency amplifiers.

amplify the signals, there being no turns ratio of transformers to aid them, there should be three stages used in this type in order to get good volume. See *Fig. 43A* for circuit of impedance coupled amplification.

The advantages of the resistance coupled type of amplifier is in its low initial cost, the high plate

voltages that may be used and its relatively distortionless output. The disadvantage is the same as that mentioned last in the previous paragraph, the use of three stages of amplification being almost imperative.

The pushpull amplifier (see *page 97*) is conceded to be the best all-around type, but the initial and upkeep costs should be considered.

The Parts and How They Are Connected for the Impedance Coupled Type of Amplifier.—You will need the following parts, (1) 3 amplifier vacuum tubes; (2) 3 tube sockets; (3) 3 impedances or auto-formers; (4) 3 grid resistors, values 0.1, 0.25 and 1 megohm; (5) 3 condensers, fixed type, 1 mf. capacity; (6) a 4.5 volts "C" battery; (7) an "A" battery; (8) a "B" battery capable of delivering 120 volts; (9) a rheostat for the "A" battery; (10) a loud speaker.

The circuit of the impedance-coupled amplifier is shown in *Fig. 43A*. This circuit can be employed with any type of detector by connecting the plate of the detector tube to the center tap of the impedance coil and the positive "B" detector plate voltage to the end of the same coil. These connections are shown at Input in the diagram.

The Parts and How They Are Connected for a Resistance-Coupled Amplifier.—You will require the following parts: (1) 3 amplifier vacuum tubes; (2) 3 tube sockets; (3) 3 resistors, values 0.1 megohm; (4) 4 fixed condensers, capacities .00025 mf., .005 mf. and two of .006 mf.; (5) 3 grid resistors, values 0.1, 0.25 and 1 megohm; (6) a "B" battery capable

of delivering 175 volts; (7) an "A" battery; (8) a 4.5 volts "C" battery; (9) a rheostat for the "A" battery; (10) a loud speaker.

The connections for this amplifier are shown in *Fig. 43B*. As in the case of the impedance-coupled

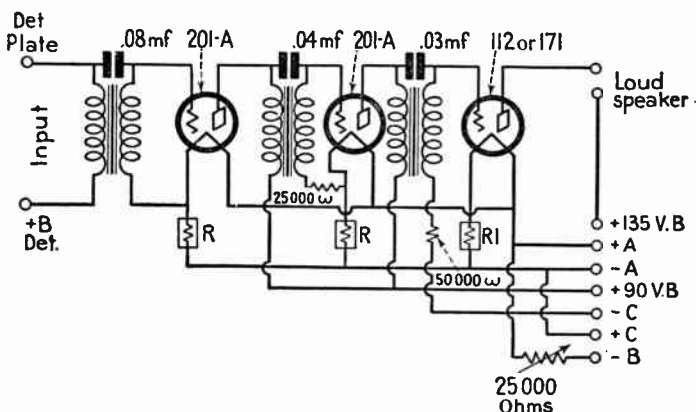


FIG. 44.—A double impedance-coupled amplifier.

type, this amplifier can be used with any type tuner, the connections being made to the Input terminals.

It should be noticed that when amplifiers are spoken of as being "distortionless" it means only that they will reproduce exactly what is put into them. Do not expect audio-frequency amplifiers to take howls out of oscillating radio-frequency amplifiers or squealing regenerative detectors.

Recently there has been announced a new system of audio-frequency amplification, which is called double impedance coupling. In *Fig. 44* is shown the circuit of an amplifier of this type. This amplifier can be so adjusted that it compensates for any

discrepancies in the loud speaker, the result being reproduction of the highest quality.

The Parts for a Double Impedance A-F. Amplifier.—You will need the following parts; three double impedance units; three fixed coupling condensers, values being .08, .04 and .03 mf.; two $\frac{1}{4}$ ampere, 5-volt filament ballasts; one $\frac{1}{2}$ ampere, 5-volt filament ballast; one fixed resistor, 25,000 ohms; one fixed resistor, 50,000 ohms; one variable resistor, 25,000 ohms, three vacuum tube sockets; two 201-A vacuum tubes; one 112 or 171 power amplifier; "A," "B" and "C" batteries.

The quality of reproduction that may be had with this amplifier is due to the fact that use is made of regeneration, which is usually the curse of amplifiers. This is adjusted by means of the resistors in the grid return leads of the second and third tubes. These are shown as fixed resistances in the diagram, for the values given have been determined as being about correct for the average loud speaker. If the experimenter wishes to better his results and to learn something more about the amplifier, variable resistors can be inserted instead of the fixed ones. The coupling condensers in some cases come in the same case as the impedance unit and in that case, of course, the ones shown are not included in the circuit.

An audio-frequency transformer is diagrammed in *Fig. 45* and a wiring diagram showing how the tubes are connected in *cascade* with the transformers is shown in *Fig. 50*.

A Pushpull Amplifier.—If you want the best in the way of *audio-frequency amplifiers*, one that will

give you immense volume and undistorted speech and music, the *pushpull amplifier* is the one to build. In this amplifier the circuit is so arranged that the energy from a single stage amplifier is fed into a second stage containing *two* amplifying tubes and special transformers, which are connected so that the energy is evenly distributed between the two tubes. The increased capacity afforded by the two tubes

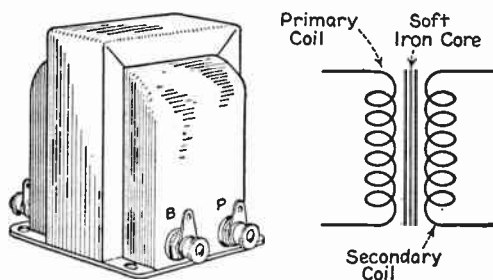


FIG. 45.—An audio-frequency transformer.

working in parallel allows for immense amplification free of distortion.

The Parts and How They Are Connected.—You will require the following parts: (1) 3 amplifier vacuum tubes; (2) 3 tube sockets; (3) a standard audio-frequency amplifying transformer; (4) 2 *pushpull amplifying transformers*; (5) a 9-volt *C* battery; (6) five 22½-volt *B* batteries; (7) an *A* battery; (8) a rheostat for the *A* battery; (9) a loud speaker.

The circuit of the *pushpull amplifier* is shown in *Fig. 46*. It should be noted that each pushpull transformer has a *center tap* and that it is taken off the *secondary winding* of the *first* transformer and off the *primary winding* of the *second* transformer. Be sure

that you get the two transformers situated correctly before starting to wire up the instruments.

A One-Tube Reflex Receiver.—Before describing this combination radio- and audio-frequency amplifier receiver it might be well to explain what is

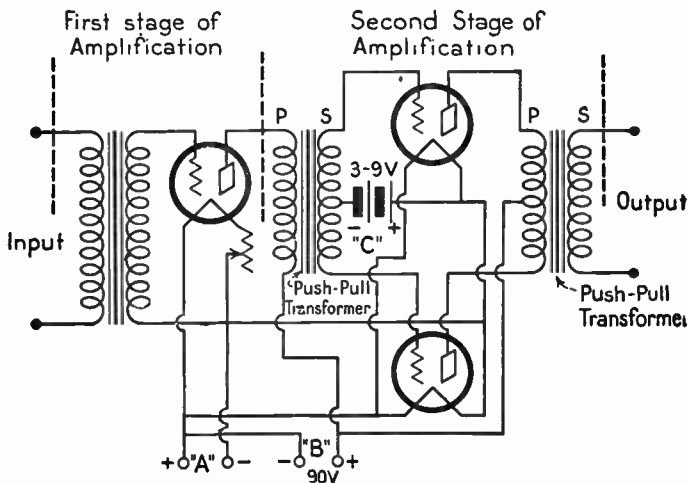


FIG. 46.—Diagram of a pushpull a-f. amplifier.

meant by *reflex*. It has until recently been a general practice to use one vacuum tube for but one purpose. Marius Latour, a well-known French inventor, found that a single vacuum tube could be so connected in a circuit as to perform two duties at practically the same time; thus, it would amplify an incoming signal before it was detected (radio-frequency) and again after it had been detected (audio-frequency). Either a crystal or another vacuum tube would be used for the purpose of rectification, but preferably a crystal. The manner in which this is accomplished is quite

simple. The incoming signal first passes through the usual tuning circuit composed of a variocoupler and a variable condenser; thence through the vacuum tube and radio-frequency amplifying transformer where it is amplified at *radio-frequency*, through the detector where it is *rectified*, through an audio-frequency transformer and back through the same tube where it is again amplified, but this time at *audio-frequency*. It then passes through the headphones or loud speaker. Thus the signal energy is fed back or *reflexed* through the same vacuum tube.

Now it is necessary that fixed condensers be placed in the circuit to allow the radio-frequency currents, before they are rectified, to by-pass the windings of the audio-frequency transformer and headphones or loud speaker which would otherwise impede the flow of the currents because of their resistance. The capacity values of these is a very important consideration in the operation of a reflex receiver. This is particularly so when employing more than one tube, and it is a very difficult proposition for the novice to find for himself the exact capacities necessary. If they are not correct the set will not operate properly. For this reason it is believed best to describe only a one-tube reflex receiver which is not difficult to construct if specifications are strictly adhered to.

The Parts You Will Need and How to Connect Them Up.—You will need the following parts for building the one-tube reflex receiver: (1) a variocoupler; (2) a 43-plate variable condenser; (3) a 23-plate variable condenser; (4) three .001-mfd. fixed condensers; (5) a 200- or 400-ohm potentiometer;

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(6) a crystal detector; (7) an audio-frequency amplifying transformer; (8) a radio-frequency amplifying transformer of the iron core type capable of covering the broadcast wavelengths which are from 220 to 550 meters; (9) three 22½-volt B batteries; (10) an A battery; (11) a rheostat; (12) an amplifier vacuum

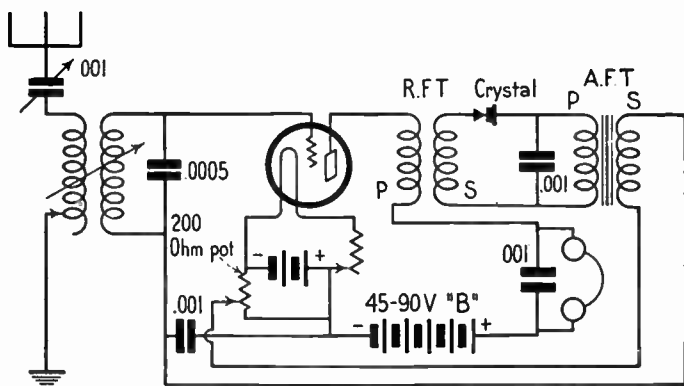


FIG. 47.—Diagram of a one-tube reflex receiver.

tube; (13) a vacuum tube socket; (14) a pair of headphones or a loud speaker.

The connections for the instruments composing this reflex set are shown in *Fig. 47*. It should be noted that the resistance wire of the potentiometer is connected directly across the terminals of the A battery exactly as explained before. The center connection or contact arm leads directly to one of the *secondary* terminals of the audio-frequency transformer.

If after completing the wiring of the circuit, the receiver fails to operate properly, the two wires connecting to the primary terminals of the audio-fre-

quency transformer should be reversed. Remember that the potentiometer plays an important part in the function of the receiver. Only by its adjustment can howling and distortion be eliminated.

How to Prevent Howling.—Where radio-frequency or audio-frequency amplifiers are used, to couple your amplifier tubes in cascade you may have to shield them from one another in order to prevent the *feedback* of the currents through them, which makes the headphones or loud speaker *howl*. To shield them from each other the tubes should be enclosed in metal boxes and placed at least 6 inches apart while the transformers should be set so that their cores are at right angles to each other and these also should be not less than 6 inches apart.

CHAPTER IX

REGENERATIVE AMPLIFICATION RECEIVING SETS

WHILE a vacuum tube detector has an amplifying action of its own, and this accounts for its great sensitiveness, its amplifying action can be further increased to an enormous extent by making the radio-frequency currents that are set up in the oscillation circuits react on the detector.

Such currents are called *feedback* or *regenerative* currents and when circuits are so arranged as to cause the currents to flow back through the detector tube the amplification keeps on increasing until the capacity of the tube itself is reached. It is like using steam over and over again in a steam turbine until there is no more energy left in it. A system of circuits which will cause this regenerative action to take place is known as the *Armstrong circuits* and is so called after the man who discovered it.

Since the regenerative action of the radio-frequency currents is produced by the detector tube itself, which sets up an amplifying effect without the addition of an amplifying tube, this type of receiving set has found great favor with amateurs, while in combination with amplifying tubes it multiplies their power proportionately and it is in consequence used in one form or another in all the better sets.

There are many different kinds of circuits which can be used to produce the regenerative amplification effect while the various kinds of tuning coils will serve for coupling them; for instance, a two or three slide, single-tuning coil will answer the purpose, but as it does not give good results it is not advisable to spend either time or money on it. A better scheme is to use a loose coupler formed of two or three

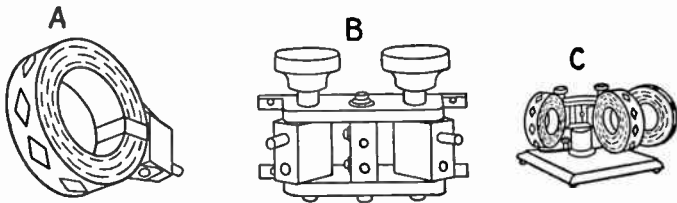


FIG. 48.—A, Honeycomb coil; B, variable mounting for three of these coils; C, coils in mounting.

honeycomb or other compact coils, while a *vario-coupler* or a *variometer* or two will also produce the regenerative action.

The Simplest Type of Regenerative Receiving Set.—While this regenerative set is the simplest that will give anything like fair results it is here described not on account of its desirability, but because it will serve to give you the fundamental idea of how the *feedback* circuit is formed.

Compact coil tuners are formed of three fixed inductances wound in flat coils, and these are pivoted in a mounting so that the distance between them and, therefore, the coupling, can be varied, as shown at A in *Fig. 48*. These coils are wound up by the makers for various wavelengths ranging from a small one that

will receive waves of any length up to 550 meters to a large one that has a maximum of 24,000 meters. For an amateur set, get three of the second smallest coils.

These three coils are mounted with panel plugs which latter fit into a stand, or mounting, so that the middle coil is fixed, that is, stationary, while the two outside coils can be swung to and fro like a door. This scheme permits small variations of coupling to be had between the coils and this can be done either by handles or by means of knobs on a panel board. While I have suggested the use of the smallest size coils, you can get and use those wound for any wavelength you want to receive, and when those are connected with variometers or variable condensers, and with a proper aerial, you will have a highly efficient receptor that will work over all ranges of wavelengths.

You can determine what coils you should use for the different wavelengths by referring to the coil table in *Chapter XII*.

The A Battery Potentiometer.—This device is simply a resistance like the rheostat described in connection with the preceding vacuum tube receiving sets but it is wound to 200- or 300-ohms resistance as against 6 to 30 ohms of the rheostat. It is, however, used as well as the rheostat. With a vacuum tube detector, and especially with one having a gas-content, a potentiometer is very necessary as it is only by means of it that the potential of the plate of the detector can be accurately regulated. The result of proper regulation is that when the critical

potential value is reached there is a marked increase in the loudness of the sounds that are emitted by the headphones.

As you will see from *A* in *Fig. 49*, it has three taps. The two taps which are connected with the ends of the resistance coil are shunted around the *A* battery

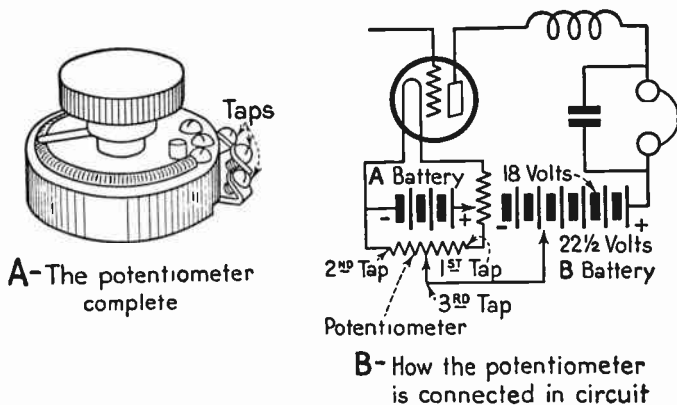


FIG. 49.—A potentiometer and how it is used.

and the third tap, which is attached to the movable contact arm, is connected with the *B* battery tap, see *B*, at which this battery gives 18 volts. Since the *A* battery gives 6 volts in this case, you can vary the potential of the plate from 18 to 24 volts. The potentiometer must never be shunted around the *B* battery or the latter will soon run down.

The Parts and How to Connect Them Up.—For this regenerative set you will need: (1) 1 honeycomb or other compact three-coil tuner, (2) 2 variable (.001 and .0005 mfd.) condensers; (3) 1 .00025 mfd. fixed condenser; (4) 1 ½ to 2 megohm grid leak;

(5) 1 tube detector; (6) *A* battery; (7) 1 rheostat; (8) 1 potentiometer; (9) 1 tapped *B* battery; (10) 1 fixed condenser of .001 mfd.; and (11) 1 pair of 2,000-ohm headphones.

To wire up the parts, connect the lead-in wire of the aerial with the primary coil, which is the left-hand one of the tuner, and connect the other terminal with the ground. Connect the ends of the secondary coil, which is the middle one, with the posts of the variable condenser, and connect one of the posts of the latter with one post of the fixed .00025 mfd. condenser, and the other post of this with the grid; then shunt the grid leak around it. Next connect the other post of the variable condenser to the - or *negative* electrode of the *A* battery; the + or *positive* electrode of this to one terminal of the detector filament, and the other end of the latter to the electrode of the *A* battery.

Now connect one end of the tickler coil with the detector plate, and the other post to the fixed .001 mfd. condenser, then the other end of this to the 18-volt tap of the *B* battery. This done, shunt the potentiometer around the *A* battery and run a wire from the movable contact of it (the potentiometer) over to the negative tap (see *B*, *Fig. 49*), of the *B* battery. Finally, shunt the headphones across the .001 mfd. fixed condenser, and you are ready to try out conclusions.

A Regenerative Audio-Frequency Amplifier Receiving Set.—The use of regenerative cascade audio-frequency receiving sets is getting to be rather obsolete, but as this is a fundamental circuit, the

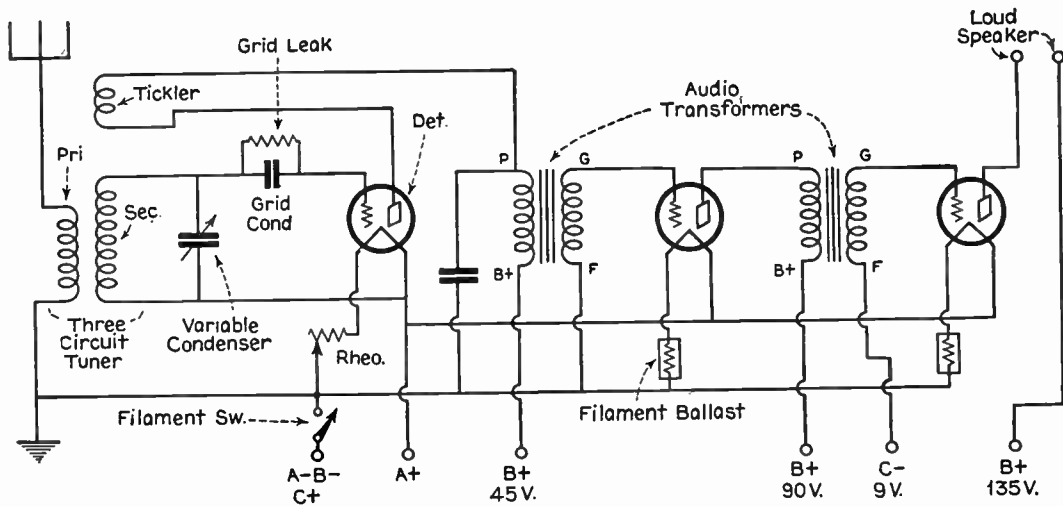


FIG. 50.—Circuit diagram of a regenerative receiver with two stages of transformer-coupled a-f. amplification.

amateur should familiarize himself with it. To get the greatest amplification possible with amplifying tubes you have to keep a negative potential on the grids. You can, however, get very good results without any special charging arrangement by simply connecting one post of the rheostat with the negative terminal of the filament, and connecting the *low-potential* end of the secondary of the tuning coil with the - or negative electrode of the *A* battery. This scheme will give the grids a negative bias of about 1 volt. You do not need to bother about these added factors that make for high efficiency until after you have got your receiving set in working order and understand all about it.

The Parts and How to Connect Them Up.—Exactly the same parts are needed for this set as the one described above, but in addition you will want: (1) two more rheostats; (2) one 45-volt *B* battery with a mid tap; (3) two amplifier tubes, and (4) two audio-frequency transformers as described in *Chapter VIII* and pictured in *Fig. 45*.

To wire up the parts, begin by connecting the lead-in wire to one end of the primary of the tuning coil and then connect the other end of the coil with the ground. A variable condenser of .001 mfd. capacity can be connected in the ground wire, as shown in *Fig. 50*, to good advantage although it is not absolutely needed. Now connect one end of the secondary coil to one post of a .001 mfd. variable condenser and the other end of the secondary to the other post of the condenser.

Next bring a lead (wire) from the first post of the

variable condenser over to the post of the first fixed condenser, and connect the other post of the latter with the grid of the detector tube. Shunt a $\frac{1}{2}$ to 2 megohm grid leak resistance around the fixed condenser and then connect the second post of the variable condenser to one terminal of the detector tube filament. Run this wire on over and connect it with the first post of the second rheostat, the second post of which is connected with one terminal of the filament of the first amplifying tube; then connect the first post of the rheostat with one end of the secondary coil of the first audio-frequency transformer, and the other end of this coil with the grid of the first amplifier tube.

Connect the lead that runs from the second post of the variable condenser to the first post of the third rheostat, the second post of which is connected with one terminal of the second amplifying tube; then connect the first post of the rheostat with one end of the secondary coil of the second audio-frequency transformer, and the other end of this coil with the grid of the second amplifier tube.

This done, connect the — or negative electrode of the A battery with the second post of the variable condenser and connect the + or positive electrode with the free post of the first rheostat, the other post of which connects with the free terminal of the filament of the detector. From this lead tap off a wire and connect it to the free terminal of the filament of the first amplifier tube, and finally connect the end of the lead with the free terminal of the filament of the second amplifier tube.

Next shunt a potentiometer around the *A* battery and connect the third post, which connects with the sliding contact, to the negative or zinc pole of a *B* battery, then connect the positive or carbon pole of it to the negative or zinc pole of a second *B* battery, and the positive or carbon pole of the latter with one end of the primary coil of the second audio-frequency transformer, and the other end of it to the plate of the first amplifying tube. Run the lead on over and connect it to one of the terminals of the second fixed condenser, and the other terminal of this with the plate of the second amplifying tube. Then shunt the headphones around the condenser.

Connect one end of the tickler coil of the tuner with the plate of the detector tube and connect the other end of the tickler to one end of the primary coil of the first audio-frequency transformer, and the other end of it to the wire that connects the two *B* batteries together. Finally, shunt a .001 mfd. fixed condenser around the primary coil of the first audio-frequency transformer.

CHAPTER X

SHORT-WAVE REGENERATIVE RECEIVING SETS

NEARLY every amateur starts in the radio game by first building a receiving set; if he does not build it, he gets one that is already assembled. However, it is a great advantage for the beginner to do as much of the building as is possible, for in no other way can he become so familiar with the different parts of the set and their functions.

In general there are two classes of receiving sets: first, those, such as we see in the homes of our friends, used for the reception of signals broadcast on the wavelength band between 200 and 550 meters; and those sets which are designed to bring in stations under 200 meters and above 550 meters. It is rather a difficult task to design a receiver that will operate efficiently *anywhere* under 550 meters, because of the peculiar action of the shorter waves, *i.e.*, those under 100 meters. However, by the use of interchangeable inductances, or coils as they are commonly called, the receivers described below have been found to give remarkable results. They have been selected because of these excellent results and because they will pick up signals from 14 to 550 meters, thus giving the amateur an instrument with which he can learn the code and also hear the regular broadcast programs from the large stations.

The short waves, those under 100 meters, are being used and studied more and more, for it has been found that they act differently than the longer waves. For instance, amateur stations, using relatively little power, have been heard on the other side of the earth, whereas it is seldom that stations using wavelengths between 200 and 550 meters and employing several kilowatts power, can boast of any such record. Amateurs have been allotted wavelength channels under 200 meters and in this they are fortunate, in that the apparatus needed is much cheaper and easier to construct than that required for operating on the longer waves.

The Pilot "Super-Wasp" receiving set, illustrated in the next few pages, is one that is easily assembled by the amateur and is cheap, the parts costing about thirty dollars, exclusive of tubes, batteries and antenna equipment. The a-c. model is slightly more expensive.

Let us consider for a moment how this receiver functions. The signals picked up by the aerial pass through the midge variable coupling condenser C10 (see *Fig. 51*), to a regular tuned input circuit connected across the filament and grid of the radio-frequency amplifier tube, UX-222, which is a screen-grid tube and described in *Chapter XIX*. The variable condenser C1 tunes this circuit and the signals are amplified at radio frequency before they are fed to the detector circuit. The coil L1 is a plain solenoid on a form which is plugged into a five-prong tube socket, while C1 is a regular .00016 mfd. variable condenser. There are five coils that are used as L1,

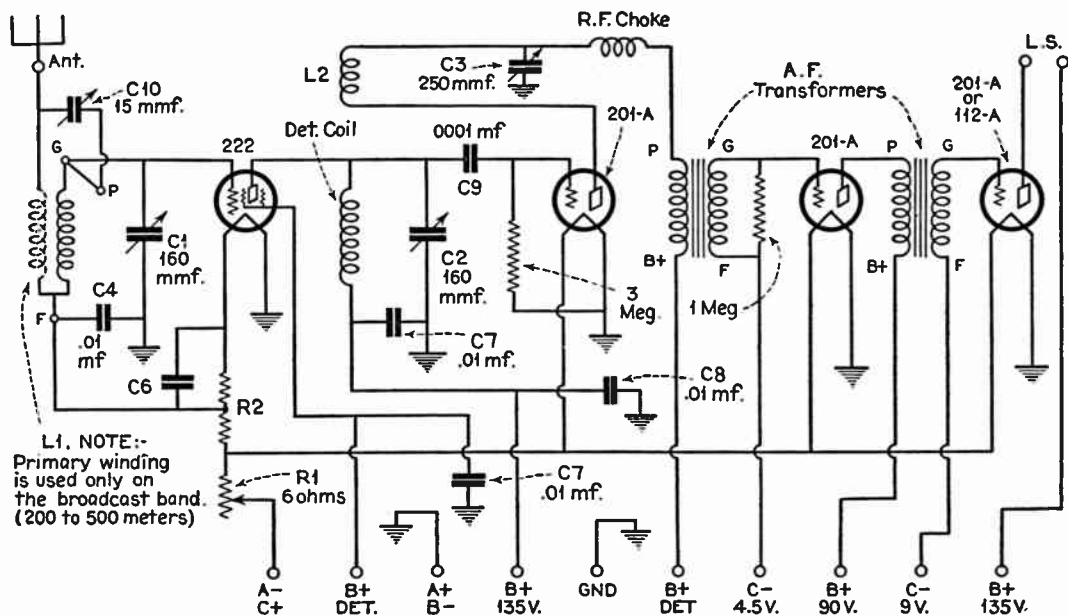


FIG. 51.—Four-tube receiver covering a wave band range from 14 to 550 meters.

as each one covers a certain wavelength band, and the same number for L2. On each of the four small coils (the largest one tuning up to 200 meters) there is merely a single winding, one end connecting simultaneously with the grid and plate terminals of the socket and the other to one of the filament posts. On the fifth and largest coil, which takes in the broadcast band (200 to 550 meters) there is a primary in addition to the grid coil, connected to the C post and the same aforementioned F or filament post. However, the bridging wire between the grid and plate terminals is absent.

By means of this arrangement, the aerial is coupled to the tuning coils of the four short-wave coils through the midget condenser, C10. This condenser is too small for the 200-550 meters region, so when the largest coil is plugged in, it is automatically cut out of the circuit and the aerial is coupled to the grid coil by means of the more adequate primary winding. There are no switches to be thrown or wires to disturb.

After the signals have been amplified in the screen-grid tube at radio frequency they pass on to the detector circuit. Here the grid and tickler coils L2 are both wound on the same form and are tuned to the same resonance as the L1-C1 circuit by the variable condenser, C2. The detector is made regenerative by the tickler coil of L2, the action being controlled by the .00025-m. variable condenser, C3.

It will be noticed there is a radio-frequency choke coil in series with the primary of the first audio-frequency transformer and the tickler coil of L2. This choke coil keeps the radio-frequency currents

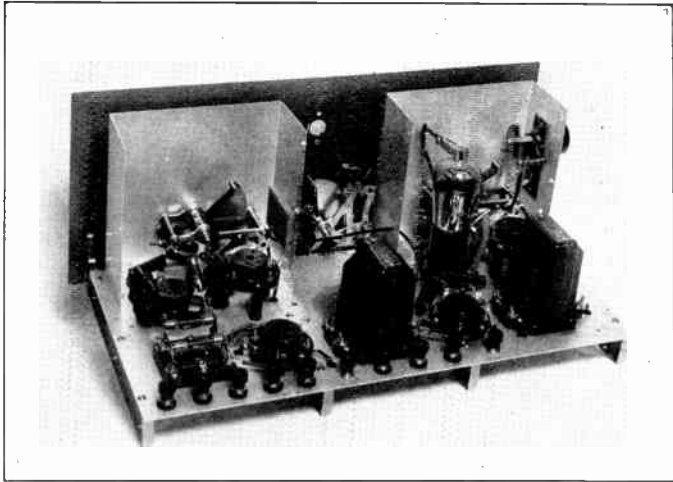
from the transformer and in no way impedes the passage of the signals after they have been detected.

The plate current for the screen-grid tube is fed to it through the detector grid coil, being kept from the grid of the detector tube V2 by the grid condenser, C9. As the rotor of the tuning condenser, C2 is grounded to the aluminum chassis of the set, the L2-C2 tuning circuit is completed by the .01 mf. condenser, C5. This condenser in series with C2 is too large to have any appreciable effect on the tuning, but prevents the "B 135" from short-circuiting against the framework. A similar blocking condenser, C4, is used in the radio-frequency stage to permit the grid of the screen-grid tube, VI, to be biased by the voltage drop across the tapped filament resistor, R2.

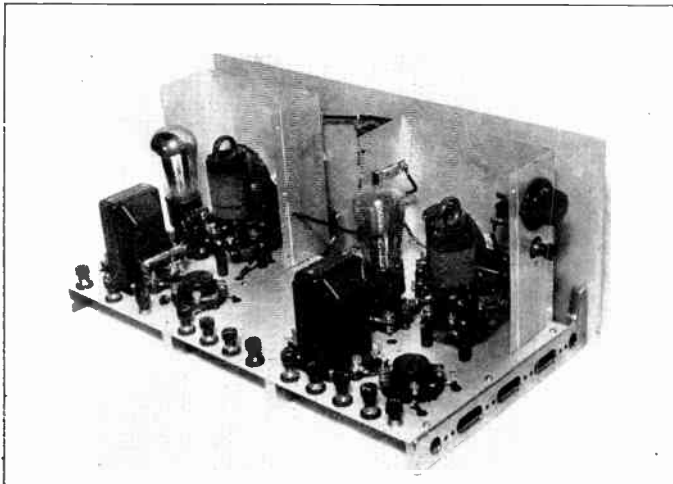
The signals are amplified after they have passed through the detector tube by the audio-frequency amplifier, which is of the transformer-coupled type. (For the theory of this amplifier see *Chapter VIII*.)

In the circuit diagram it will be noticed that there are eleven ground connections indicated. This means that the aluminum chassis of the receiver is directly connected to the ground binding post and at the other ten points of connection, instead of running a connecting wire to the ground binding post, a wire is soldered to the chassis. This simplifies wiring to a great extent.

The front and sub-panels are of metal and they come to the constructor already drilled for all the parts that are to be attached to them. The components of the antenna and detector stages, respec-



The Pilot A. C. Super-Wasp short-wave receiver, showing the back halves of the shield cans removed. Note the screen-grid tube in the radio-frequency stage.



The Pilot D. C. Super-Wasp with the back halves of the shield can removed, showing the screen-grid r-f. amplifier and the detector tubes.

tively, are enclosed with aluminum shield cans of unique design. Shielding has been found necessary in sets using radio-frequency amplifiers, to eliminate the interaction between the parts of the various stages. This interaction could be cut down by placing the parts at a greater distance, but this would make the set unwieldy.

Doubtless you are interested in what this receiver is capable of doing. During a test made in Buffalo,

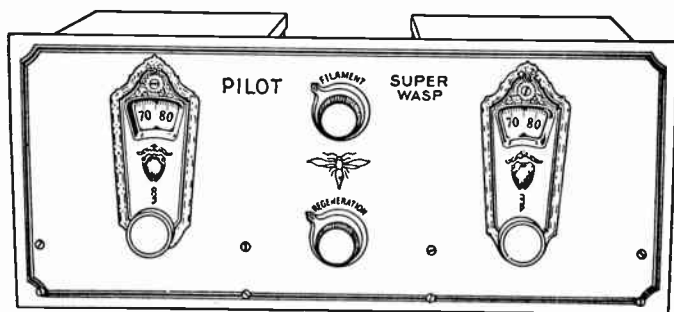


FIG. 52.—Front panel view of all-wave receiver.

N. Y., stations in Los Angeles, Cal.; Vienna, Austria; Copenhagen, Denmark; Chelmsford, England; Paris, France; Eindhoven, Holland, and Mexico City were received and in nearly every case with enough volume to operate a loud speaker.

This model is operated entirely from batteries; that is, for successful operation you will need a storage battery and enough plate or *B* batteries to give you 135 volts. Also you will need 45 volts of smaller plate batteries to furnish the grid bias or *C* voltage. It has been found that d-c. tubes and batteries are very satisfactory on short-wave sets

and so this receiver was designed to employ them.

If you intend to use this receiver exclusively on the wavelength bands under 200 meters, you will need an antenna only about twenty or thirty feet in length. While this antenna will also bring in the broadcast stations between 200 and 550 meters, a longer antenna would prove more satisfactory for the longer wavelengths.

As was mentioned previously there are five sets of coils, two to a set. These coils are wound on insulating forms of different colors, so that it is a simple matter to know in what wave band you are working. They are divided as follows: Red, 14 to 27 meters; orange, 26 to 50 meters; yellow, 50 to 100 meters; green, 100 to 200 meters, and blue, 200 to 500 meters.

The following parts are required for building the Pilot "Super-Wasp" receiver, 1 aluminum front panel, $7\frac{1}{2} \times 18 \times 1/16$ inches; 1 sub-panel, $8 \times 17 \times 1/16$ inches; 4 sub-panel brackets; 2 .00016 mf. variable condensers; 1 .00025 mf. variable condenser; 2 illuminated vernier dials; 1 6-ohm rheostat; 1 tapped resistor; 2 "Super-Wasp" shield cans; 1 5-plate midget condenser; 2 audio-amplifying transformers; 2 five prong sockets; 2 four prong sockets; 2 four prong shock-proof sockets; 1 3-megohm grid leak; 1 100,000-ohm grid leak; 1 .0001 mf. fixed condenser; 5.01 mf. fixed condensers; 1 R.F. choke coil; 2 sets of plug-in coils; hardware, screws, nuts, binding posts, insulated bushings, connection wire, etc.

The A-C. "Super-Wasp" Receiver.—The receiver about to be described is essentially the same as the previous one with the exception that it is entirely

operated from the 110-volt a-c. lighting circuit. This, of course, eliminates all battery troubles and insures at all times the correct voltages on the plates and grids of the tubes.

A great many difficulties were encountered in the design of this receiver, chief of these being the two different types of a-c. "hum." One of these was found to originate in the detector tube and was present at all wavelengths. The other hum was only in evidence at certain frequencies.

The first was reduced to a negligible quantity by redesigning the 227-type tube, used as a detector, and placing a stage of resistance-coupled amplification in place of the first transformer-coupled stage. This procedure insures excellent quality when a headset is used, which is the real test for a-c. hum.

The tunable hums—those occurring at different wavelengths—were found to be high-frequency oscillations modulated by the 60-cycle current and produced by oscillating circuits composed of the capacities present in the tube detector and the leads going to the center-tapped resistor. By the insertion of by-pass condensers, these hums were eliminated.

The operation of this receiver is the same theoretically as the d-c. model described previously, so that phase of it need not be gone into. Suffice to say, engineers claim that the a-c. screen-grid tube, such as is used in this set, is more sensitive than the d-c. 222-type. This should mean an improvement in the a-c. model.

The power-supply unit, which is shown in an accompanying illustration, gives all the required voltages

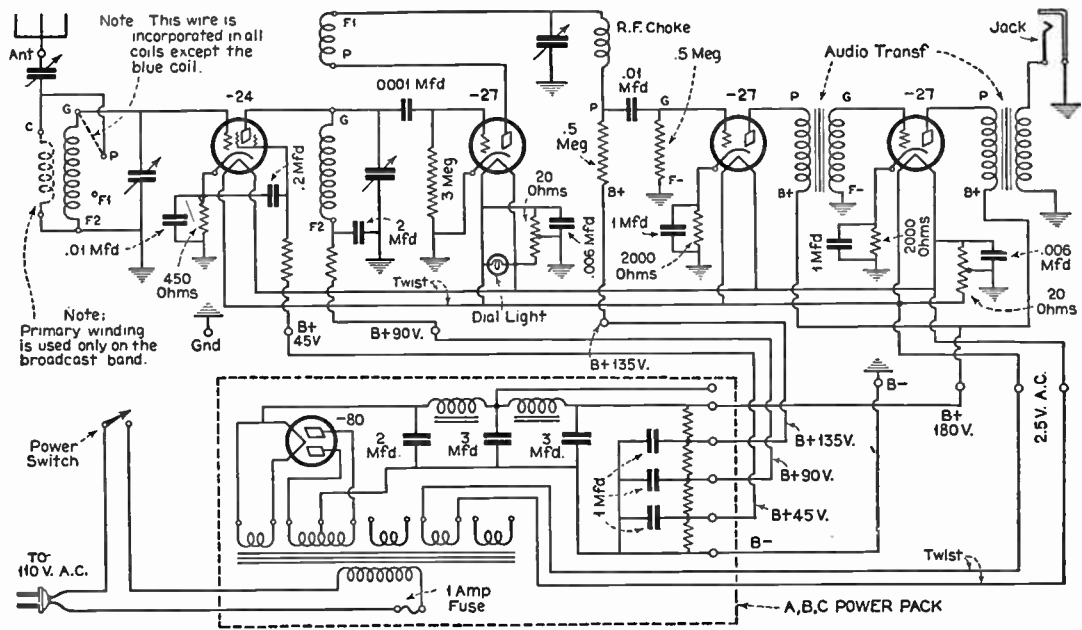


FIG. 53.—Complete wiring diagram of Pilot "Super-Wasp" a-c. receiver and power-supply unit.

for the filaments, plates and grids of the four tubes. A full wave rectifier tube, UX-280, is employed. See circuit diagram, *Fig. 53*.

The following apparatus is required for the construction of the A-C. Super-Wasp:

- 1 front and 1 sub-panel
- 1 pair of shield cans
- 4 metal shelf brackets
- 2 vernier dials
- 1 110-volt snap switch
- 2 .00016 mf. variable condensers
- 1 .00025 mf. variable condenser
- 1 .000015 mf. variable midget condenser
- 1 .01 mf. fixed condenser
- 1 .0001 mf. fixed condenser
- 2 .006 mf. fixed condensers
- 2 1 mf. bypass condensers
- 2 0.2 mf. bypass condensers
- 1 a-f. transformer
- 1 output transformer
- 3 450-ohm resistors
- 2 200-ohm resistors
- 2 20-ohm center-tapped resistors
- 2 0.5 megohm grid leaks
- 1 3 megohm grid leak
- 2 sets of plug-in coils
- 1 80-millihenry r-f. choke coil
- Necessary hardware
- Power-supply unit
- 3 special 227-type tubes and 1 224-screen-grid a-c. tube

A Super-regenerative Receiving Set. — This is a very interesting development in radio and is an entirely new kind of regenerative receiving system. Like those described in the previous and following chapters, it is the invention of Major E. H. Arm-

strong. It is, however, based on an entirely different principle and it is as great an advance over the original regenerative system, as the latter was over the simple vacuum tube detector scheme. However, the circuit is quite unstable and the amateur is cautioned that it will prove extremely difficult to operate.

The super-regenerative system is of especial interest to the amateur for it does what the ordinary regenerative circuit cannot do; it amplifies the energy of short waves inversely as their wavelength. This means that the shorter the wavelength the greater it will be amplified. Thus the energy of a wave that is 100 meters long is amplified four times as much as when the wave is 200 meters long. Super-regeneration can be accomplished by using one, two or three vacuum tubes.

The Parts and How to Connect Them Up.—For this set you will have to get the following parts: (1) one variocoupler; (2) one .0025 mfd. variable condenser; (3) two 6-volt *C* batteries; (4) one amplifier tube; (5) three filament rheostats; (6) one 90- to 135-volt *B* battery; (7) two honeycomb or duolateral coils, of 1250 and 1500 turns respectively; (8) one .0025 mfd. fixed condenser; (9) one .001 mfd. variable condenser; (10) one 5-millihenry air core choke coil; (11) one oscillator tube; (12) one 6-volt storage battery; (13) two .001 mfd. fixed condensers; (14) two 12,000-ohm resistances; (15) one .005 mfd. variable condenser; (16) one 100-millihenry iron core choke coil; (17) one audio-frequency amplifier transformer; (18) one detector tube; (19) one 225-

volt *B* battery, and (20) one set of headphones or a loud speaker.

When a loop aerial is used, it may be provided with an adjustable clip so that the number of turns of wire, and, hence, its inductance, can be varied. All three vacuum tubes used for this receiving set can be either *amplifier tubes*, or they can be *5-watt oscillator tubes* of the *hard type*, that is they must be exhausted to a high degree. Low voltage tubes such as the WD-11 cannot be used.

The *A* battery for heating the filaments of the tubes where the latter are of the usual amplifier type is a 6-volt one. The battery connected in the grid circuit to give the grid a negative voltage is known as the *C battery*, and this is formed of four dry cells. For the *B* battery, which is the plate battery, enough 22½-volt *B* batteries can be connected in series to give the high voltage necessary.

The honeycomb, or duo-lateral coils (see *Fig. 48*) are not connected together inductively as they are when used for tuning coils, but instead they are set in a line, or at right angles to each other and at some little distance apart. The 5-millihenry coil can also be a honeycomb, or duo-lateral coil which has this value of inductance. The 100-millihenry coil is wound on an iron core and so acts as a choke coil. Finally the *lavite resistances* are formed of high-resistance wire wound on a heat-resisting material called *lavite*.

The way in which the parts are connected together is clearly shown in the diagram, *Fig. 54*. Before you build this super-regenerative set, or try to adjust one that is already built, be sure to read the

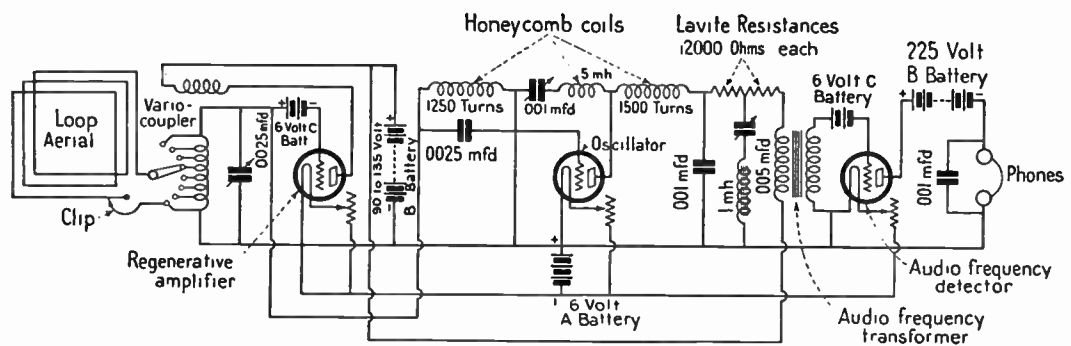


FIG. 54.—Wiring diagram of the Armstrong Super-regenerative receiver.

explanation of the way it works in *Chapter XVIII*, or you will more than likely make a failure of it.

A Reinartz Regenerative Receiving Set.—The Reinartz circuit has gained considerable popularity because of its ability to receive over long distances, the ease with which it can be handled and its comparatively low cost of construction. This circuit incorporates the advantages of the three circuit receiver for selectivity and of the single circuit receiver for sensitivity to weak signals. Furthermore, both *capacitive* and *inductive* feedback or regeneration are combined so as to take advantage of the good qualities of both. The antenna circuit is *semi-aperiodic*, that is, it is capable of transferring energy to the secondary, which in this case is *conductively coupled* to it, over a wide band of wavelengths without any appreciable loss and without the usual fine adjustments necessary in the case of a *periodic* or *tuned primary* circuit. Having the secondary coil connected *directly* to the primary coil allows a direct flow of energy into it, and at the same time provides for a step up in voltage which is very desirable in a vacuum tube circuit.

As has been pointed out, the Reinartz receiver is easy to operate and the three switches provided are used only when large changes in wavelength are required. This boils down the important controls to the two variable condensers, one for *tuning* and the other for *regeneration*. From the diagram of this circuit it is seen that there are two coils, one being the *tickler*. They are both wound on the same form, however, and the coupling between them is *fixed*.

The Parts and How to Connect Them Up.—The parts you will need for building this set are: (1) a *Reinartz Spider-web coil*; (2) two 23 plate variable condensers; (3) an *A* battery; (4) a 22½-volt *B* battery; (5) a rheostat; (6) a grid leak; (7) a .00025 mfd. grid condenser; (8) 15 switch points and 6 switch stops; (9) 3 switch arms; (10) a vacuum tube

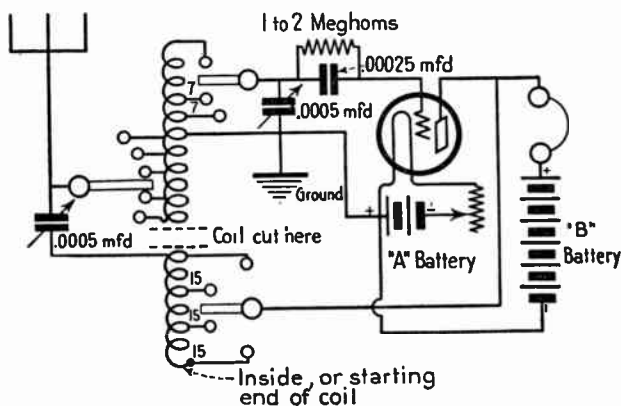


FIG. 55.—Wiring diagram of the Reinartz regenerative receiver.

detector; (11) a tube socket; (12) a pair of headphones.

The wiring of the various parts can be easily followed from the diagram of the circuit in *Fig. 55*. It should be noted that the inside wire, or *starting end*, is the *tickler coil* and the next four tap wires are a part of it. The 5th, 6th, 7th, 8th and 9th tap wires from the center compose the *primary coil* and the last three are the *secondary connections*.

Before purchasing any of the parts, the vacuum tube chart in the back of the book should be consulted

and the type of vacuum tube you wish to use decided upon. Then *make sure* that you get the right kind of rheostat, A battery, etc., for this tube.

A Cockaday Four-Circuit Regenerative Receiver.—This circuit has a number of advantages over similar types of regenerative receivers. Its merits can be understood from the following explanation: One of the most sensitive of regenerative circuits is the original *DeForest Ultra Audion* receiver. It has one drawback, however, in that it is very difficult to keep the circuit from *oscillating*. Naturally this is detrimental to good reception.

Mr. Lawrence Cockaday devised a means to stabilize the action of the Ultra Audion circuit and this he did by the use of what is known as an *absorption* or *sensitizing* circuit. This circuit is in no way connected to any other portion of the circuit but is merely in *inductive relation* or, in other words, coupled to the coil in the grid circuit. Its function there is to *absorb* just enough energy from the grid circuit to keep it from oscillating and this it does very well. It should be remembered that it is the *feedback* action that creates both *regeneration* and *oscillation*. Since the feedback in the Ultra Audion circuit is difficult to control it is easy to understand that if too much energy is transferred from the plate to the grid circuit, the *absorption* or *fourth circuit* in this receiver will control it. The primary or antenna circuit of this receiver is, like the Reinartz, *semi-aperiodic* but *inductive* rather than conductive coupling is employed. As seen from the diagram of the circuit in *Fig. 56*, the coupling coil consists of but *one turn of wire*.

The Parts and How to Connect Them Up.—For this set you will need: (1) a *Cockaday coil unit* (you can purchase this at any radio store); (2) two 23 plate variable condensers; (3) an *A* battery; (4) a 22½-volt *B* battery; (5) a rheostat; (6) a grid leak;

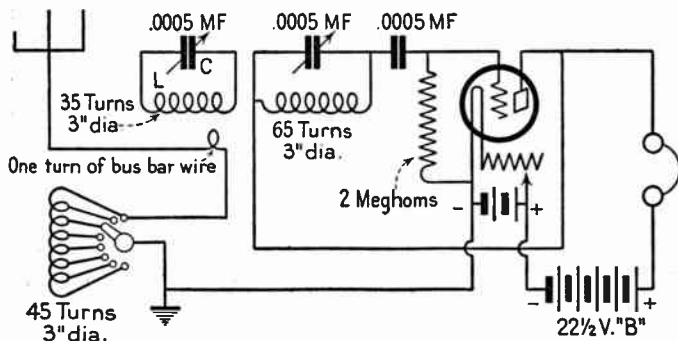


FIG. 56.—Wiring diagram of the Cockaday four-circuit receiver.

(7) a .0005 mfd. grid condenser; (8) 8 switch points and 2 switch stops; (9) a switch arm; (10) a vacuum tube detector; (11) a tube socket; (12) a pair of headphones.

The circuit diagram is shown in *Fig. 56* and is easy to follow. It differs slightly from the average hook-up, in that the *grid leak* instead of being connected directly across the grid condenser, is run from between it and the grid of the tube to the negative terminal of the filament of the vacuum tube. This connection is *important* and should be strictly followed.

CHAPTER XI

THE HAMMARLUND "HI-Q 30" RECEIVER

IN the selection of a receiver for picking up the programs sent out from broadcast stations, three factors should be considered: sensitivity, selectivity and the quality of reproduction. Some of the receivers on the present-day market have two of these qualifications, but it is seldom that a broadcast receiver has all three, unless the price is far beyond the average pocketbook.

The matter of circuit is an all-important one. In the past few years the advent of new circuits has fallen off, the tendency now being to make the standard circuits operate in a more efficient manner, and to bring nearer to perfection the apparatus with which we have to work. The Hi-Q 30 circuit is one that not only functions in a highly satisfactory manner, but is interesting from the student's viewpoint.

In order to present to the reader a receiver that is modern in every respect and one which may be built for a reasonable figure, the Hi-Q 30 was chosen and it is one that should stand the test of time. The various necessary units may be had at your local radio dealer and to insure the best results purchase only the standard equipment.

A Receiver's Requirements.—Before taking up the matter of the circuit's theory, let us consider for

a moment what the requirements are for a modern receiver. In the matter of selectivity, the wavelength of broadcast stations in the United States have been so allotted that no station will interfere with another's signals in the same vicinity. However, as a modern set should be able to receive stations from a considerable distance, it is imperative that the set be able to separate the signals of stations at least 20 kilocycles apart. It is relatively simple to do this, but often at a sacrifice of the quality of reproduction, as the sidebands of the signals are cut off. Therefore, we must have a set that is selective and yet will preserve the sidebands of the wave.

Now sensitivity. We all like to hear stations a long distance from us; that is one of radio's greatest charms. In order that a set may pick up distant signals it is necessary to have at least two stages of radio-frequency amplification before the detector tube. Here again trouble is likely to be met unless the circuit is so designed that interference between the r-f. stages is eliminated. Also the detector circuit must be sensitive and operate efficiently or the amplified signals will not be rectified as they should be and losses will be introduced.

As to quality of reproduction, this is a subject on which the whole design of the circuit, apparatus and accessories, depends. Many people blame the poor quality of music coming from their loud speakers on that much-abused instrument when in reality the fault lies somewhere in the set itself. Distortion may be introduced in any number of places in the set, but one of the commonest places is in the audio-

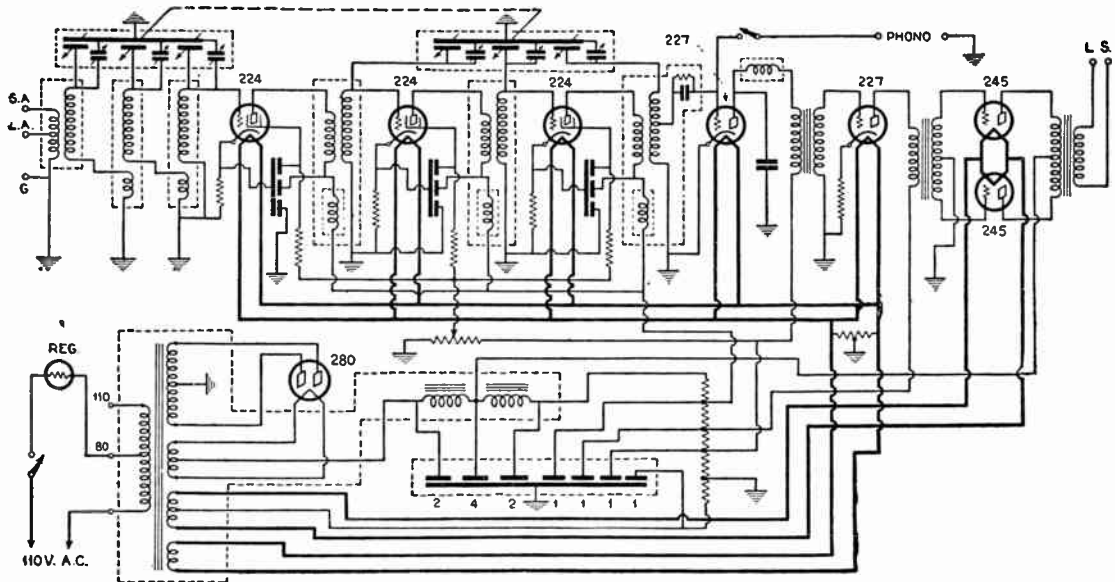


FIG. 57.—Complete wiring diagram of the "Hi-Q 30" a-c. receiver and power-supply unit.

frequency amplifier. This must be designed to do the work expected of it and it is useless to force it to do other things than those for which the designer intended it to be used. Loud speakers are in the same class.

The Theory of the Circuit.—The complete circuit diagram of the Hi-Q 30 will be seen in *Fig. 57*. It has three stages of tuned radio-frequency amplification, a detector and two stages of audio-frequency

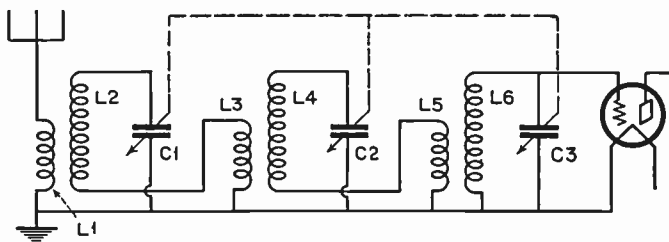


FIG. 58.—The multi-tuned antenna circuit used in the "Hi-Q 30" receiver.

amplification, the last one consisting of two 245-tubes connected in pushpull. The circuit shown uses the newest type of alternating-current vacuum tubes and is complete with the necessary power-supply unit, which has as a rectifier a 280-type tube, and the filter system for smoothing out the rectified current.

It will be noticed in *Fig. 57* that there are three tuned circuits before the first 224-tube. This may perhaps be more clear if *Fig. 58* is consulted, which is the same circuit as the other—up to the first tube—but simplified. The following inductances are in inductive relationship to each other: L1-L2, L3-L4, and L5-L6. It will be seen that the secondary coil

L2 and L3, the primary of the second set, are in series, the condenser C1 being shunted across the pair. The same is also true with L4 and L5. The three variable condensers, C1, C2 and C3 operate from the same control and rotate together.

This multi-tuned antenna circuit was developed by Dr. George A. Somersalo, a Finnish physicist. It forms a very effective frequency wave filter and operates as follows: The distributed capacity of the coil L3 causes a current to flow in it and this small current induces a field around the secondary L4 and sets up a much greater current. The same procedure takes place in L5 and L6, whence the current is impressed on the grid and filament of the first r-f. amplifier tube. The action is really an amplifying one because of the step-up transformers, L3-L4 and L5-L6, and the signals after passing through this filter are about as strong as they were in the antenna. This system of coils forms an efficient filter to all incoming radio signals and lets through only a narrow band of frequencies, which is desired to pick-up and amplify.

The great advantage of passing through a *band* of frequencies may be more fully realized upon consulting *Fig. 59*. In *A* of this diagram is the typical response curve of an average tuned radio-frequency receiver. (It must be remembered that a broadcast station puts on the air a modulated carrier frequency which has two sidebands each 10 kilocycles wide. It is the passing through the set of these sidebands efficiently that makes for good quality.) When the variable condensers of this average receiver are ro-

tated the resonance of the set is varied and when a station is tuned-in we have a peaked curve such as the one shown in *A*. This is evidenced by the fact that we can vary the condensers a trifle and still hear the signals but they are fainter due to the curve of *A*

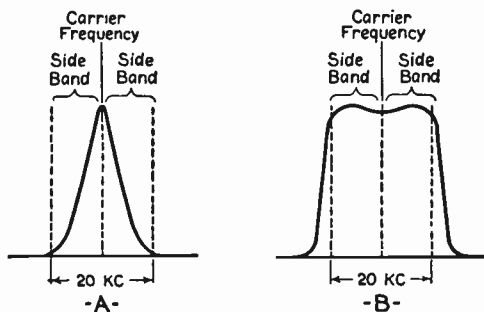


FIG. 59A.—The response curve of a typical tuned r-f. receiver. FIG. 59B.—The response curve of a receiver having a special filter in the r-f. amplifier.

dropping off from the peak of resonance. Also we do not get the full value of the sidebands, as may easily be seen.

The reverse is true when a receiver has a response curve, such as is shown in *Fig. 59*. By a system of filters we can eliminate the sharp resonance peak and spread the curve over the two sidebands. This necessitates a very nice adjustment of the components of the filter, as the slope of the curve must be very steep, so that it will pass only the 20 kilocycles to which we wish to listen. In *B* it will be seen that the band of frequencies passed on to the detector and a-f. amplifier embraces all the frequencies put on the air at the broadcast station.

The Hammarlund "Hi-Q 30" Receiver 135

The three-stage, radio-frequency amplifier is of the regulation type, except that there are inserted at every point where necessary by-pass condensers and r-f. choke coils, so that no vagrant currents can interfere with the proper functioning of the amplifier. The three variable condensers connected in parallel across the secondaries of the r-f. transformers are operated together from the one main control together with the three condensers of the antenna filter circuit already explained. It will be noted in *Fig. 57* that across each main variable condenser is a smaller one, these being to adjust the capacities to the coils so that everything will be in perfect balance. Once adjusted these trimmer condensers need not be again touched.

The various inductances and condensers described above are all shielded in aluminum boxes in order to eliminate as far as possible any interference between circuits.

The first three tubes of the circuit, those of the r-f. amplifier, are of the screen-grid type, thus making for further stability and greater amplification. These three together with the detector and first audio amplifier are of the heater-type a-c. tube, insuring quiet operation and absence of any hum. The power tubes in the pushpull stage can be supplied with either a-c. or d-c. on the filament, for reasons that have been explained in the chapter devoted to vacuum tubes.

The Power-Supply Unit.—For those radio enthusiasts who have alternating current power in their homes, it is advised that they build the a-c. type of

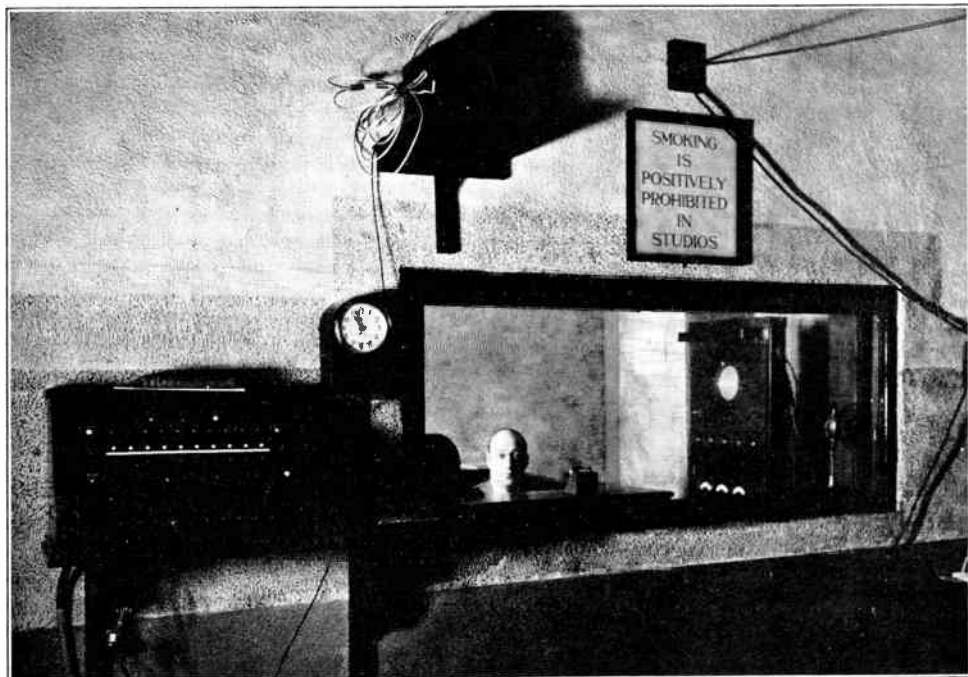
receiver, for they thereby eliminate all trouble of storage battery, "B" batteries, etc., and the operation is as satisfactory.

The power unit consists of a power transformer, which has four secondary windings, used as follows: a 750-volt center-tapped winding with 100-milliamperere rating for the plate currents; a 5-volt, 2-ampere winding for the filament of the 280-rectifier tube; 2½-volt, 3-ampere winding for the filaments of the 245-tubes; and a 2½-volt, 9 ampere winding for the heaters of the rest of the tubes in the set.

The two 30-henry filter chokes and the bank of condensers smooth out the rectified current for the various plates of the tubes. Different voltages are had by tapping the resistor shunted across the output of the filter system, thereby taking advantage of the drop in voltage across the various resistances.

The primary of the power transformer is tapped at 80 volts so that a voltage regulator may be inserted in the line. This device maintains the voltage fed to the transformer at a constant value, no matter how much the line voltage fluctuates.

In the grid circuit of the detector tube it will be noted that there is provision made for connecting a phonograph pick-up. The set may be switched from operating as a radio to phonograph operation by the throwing of this single switch, which is located at the grid terminal of the detector tube. The output of the phonograph pick-up goes to the audio-frequency amplifier, which is more than sufficient to fill an ordinary-sized home with music.



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On the left the announcer's signal board for communicating with the monitor shown in his booth.

The Parts and How They Are Connected.—The following parts are required for constructing the Hi-Q 30 receiver:

- 1 three-stage Band Filter Unit
- 1 three-stage screen-grid amplifier unit
- 1 knob-control drum dial
- 1 shielded polarized r-f. choke coil
- 1 first stage a-f. transformer
- 1 pair pushpull transformers
- 1 power supply unit
- 3 screen-grid tube shields
- 1 filter condenser block
- 3 triple by-pass condensers
- 1 center-tapped 10-ohm resistor
- 1 pair phone tip jacks
- 1 voltage divider
- 1 1500-ohm flexible grid resistor
- 3 400-ohm flexible grid resistors
- 3 5000-ohm flexible grid resistors
- 1 25,000-ohm volume control potentiometer
- 1 2-prong socket for voltage regulator tube
- 3 4-prong sockets
- 5 5-prong sockets
- 1 binding post strip
- 2 toggle switches
- 1 .001 mf. fixed condenser
- 1 foundation unit, containing hardware, cabinet, shields, etc.

This list will be somewhat changed of course, if a battery-operated set is desired. The type of loud speaker to be used with this receiver is at the option of the individual, but a dynamic type is recommended, as the output of the set will be more than sufficient for a dynamic's needs and the resultant quality will be most satisfying. If desired, an electrically-driven phonograph turntable may be had

to be installed in the same cabinet or console with this receiver, making an excellent combination.

The construction of this Hi-Q 30 is simplicity itself, as most of the connections are made at the factory before the set is shipped. This eliminates all balancing and adjusting by the constructor, and assures him of a set capable of efficient operation if assembled properly.

The antenna requirements for this receiver are most meager. If only local stations are desired no antenna is necessary. A sheet of copper screening tacked on the rear of the cabinet or console will bring in stations up to 200 miles distant. A wire strung about the picture molding of an average-sized room will also give good results.

Of course, if you are interested in DX then an outside antenna is essential, such as is described in the chapter devoted to that subject.

CHAPTER XII

INTERMEDIATE - AND LONG-WAVE REGENERATIVE RECEIVING SETS

ALL receiving sets that receive over a range of wavelengths of from 200 meters to 3,000 meters are called *intermediate-wave sets* and all sets that receive wavelengths over a range of anything more than 3,000 meters are called *long-wave sets*. *Short-wave receivers* are those capable of receiving stations within the 15-200 meter waveband. The range of intermediate-wave receptors is such that they will receive broadcasting, ship and shore Navy, commercial, Arlington's time and all other stations using *spark telegraph damped waves* or *arc* or *vacuum tube telephone continuous waves* and *continuous wave telegraph signals*. Just how these receivers can receive *continuous wave telegraph signals* is described in *Chapter XIII*.

Intermediate-Wave Receiving Sets.—There are two chief schemes employed to increase the range of wavelengths that a set can receive and these are by using: (1) *loading coils* and *shunt condensers*, and (2) *bank-wound coils* and *variable condensers*. If you have a short-wave set and plan to receive intermediate waves with it then loading coils and fixed condensers shunted around them affords you the way to do it, but if you prefer to buy a new receiver then the better way is to get one with bank-wound

coils and variable condensers; this latter way preserves the electrical balance of the oscillation circuits better, the electrical losses are less and the tuning easier and sharper.

Intermediate-Wave Set with Loading Coils.—For this intermediate-wave set you can use either of the short-wave sets described in the foregoing chapter. For the loading coils use *honeycomb coils*, or other good compact inductance coils, as shown in *Fig. 48* and having a range of whatever wavelength you wish to receive. The following table shows the range of wavelength of the various sized coils when used with a variable condenser having a .001 microfarad capacity, the approximate *inductance* of each coil in *millihenries* and prices at the present writing:

TABLE OF CHARACTERISTICS OF HONEYCOMB COILS

| Millihenries Inductance Appx. | Approximate Wavelength in Meters in Shunt with a .001 mfd. Variable Air Condenser | Mounted on Plug |
|-------------------------------------|--|--------------------|
| .040 | 130- 375 | \$1.40 |
| .075 | 180- 515 | 1.40 |
| .15 | 240- 730 | 1.50 |
| .3 | 330- 1030 | 1.50 |
| .6 | 450- 1460 | 1.55 |
| 1.3 | 660- 2200 | 1.60 |
| 2.3 | 930- 2850 | 1.65 |
| 4.5 | 1300- 4000 | 1.70 |
| 6.5 | 1550- 4800 | 1.75 |
| 11. | 2050- 6300 | 1.80 |
| 20. | 3000- 8500 | 2.00 |

TABLE OF CHARACTERISTICS OF HONEYCOMB
COILS—*Continued*

| Millihenries Inductance Appx. | Approximate Wavelength in meters in Shunt with a .001 mfd. Variable Air Condenser | Mounted on Plug |
|-------------------------------------|--|--------------------|
| 40. | 4000-12000 | 2.15 |
| 65. | 5000-15000 | 2.35 |
| 100. | 6200-19000 | 2.60 |
| 125. | 7000-21000 | 3.00 |
| 175. | 8200-24000 | 3.50 |

These and other kinds of compact coils can be bought at electrical supply houses that sell radio goods. If your aerial is not very high or long, you can use loading coils, but to get anything like efficient results with them you must have an aerial of large capacity, and the only way to get this is to put up a high and long one with two or more parallel wires spaced a goodly distance apart.

The Parts and How to Connect Them.—Get (1) *two honeycomb or other coils* of the greatest wavelength you want to receive, for in order to properly balance the aerial, or primary oscillation circuit, and the closed, or secondary oscillation circuit, you have to tune them to the same wavelength; (2) *two .001 mfd. variable condensers*, though fixed condensers will do, and (3) *two small single-throw double-pole knife switches* mounted on porcelain bases.

To use the loading coils, connect one of them in the aerial above the primary coil of the loose coupler, or variocoupler as shown in the wiring diagram in A of *Fig. 60*, and then connect one of the switches

around this; this switch enables you to cut in or out the loading coil at will. Likewise connect the other loading coil in one side of the closed, or secondary

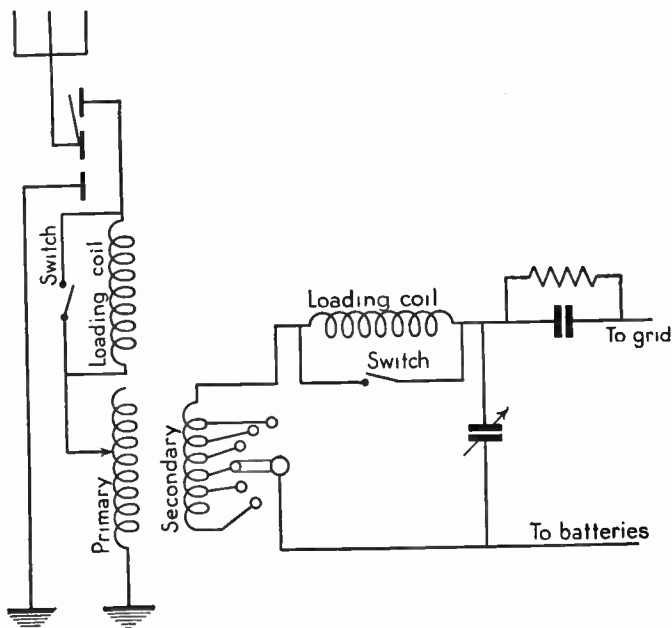


FIG. 60A.—Wiring diagram showing fixed loading coils for intermediate-wave receiver.

circuit between the variable .0007 mfd. condenser and the secondary coil of the loose coupler or variocoupler.

An Intermediate-Wave Set with Variocoupler Inductance Coils.—By using the coil wound on the rotor of the variocoupler as the tickler, the coupling between the detector tube circuits and the aerial wire system increases as the set is tuned for greater

wavelengths. This scheme makes the control of the regenerative circuit far more stable than it is where an ordinary loose coupled tuning coil is used.

When the variocoupler is adjusted for receiving very long waves the rotor sets at right angles to the stator and, since when it is in this position there is no mutual induction between them, the tickler coil serves as a loading coil for the detector plate oscillation circuit. Inductance coils for short wavelengths are usually wound in single layers, but *bank-wound coils*, as they are called, are necessary to get compactness where long wavelengths are to be received. By winding inductance coils with two or more layers, the highest inductance values can be obtained with the least resistance. A wiring diagram of a multipoint inductance coil is shown in *B* of *Fig. 60*. You can buy this intermediate-wave set assembled and ready to use or get the parts and connect them up yourself.

The Parts and How to Connect Them.—For this regenerative intermediate-wave set get: (1) one *12 section triple bank-wound inductance coil*, (2) one *variocoupler*, and (3) all the other parts shown in the diagram *B* of *Fig. 60* except the variocoupler. First connect the free end of the condenser in the aerial to one of the terminals of the stator of the variocoupler; then connect the other terminal of the stator with one of the ends of the bank-wound inductance coil and connect the movable contact of this with the ground.

Next connect a wire to the aerial between the variable condenser and the stator and connect this to one post of a .0005 microfarad fixed condenser, then con-

nect the other post of this with the grid of the detector and shunt a grid leak around it. Connect a wire to the ground wire between the bank-wound inductance coil and the ground proper, *i.e.*, the radiator or water

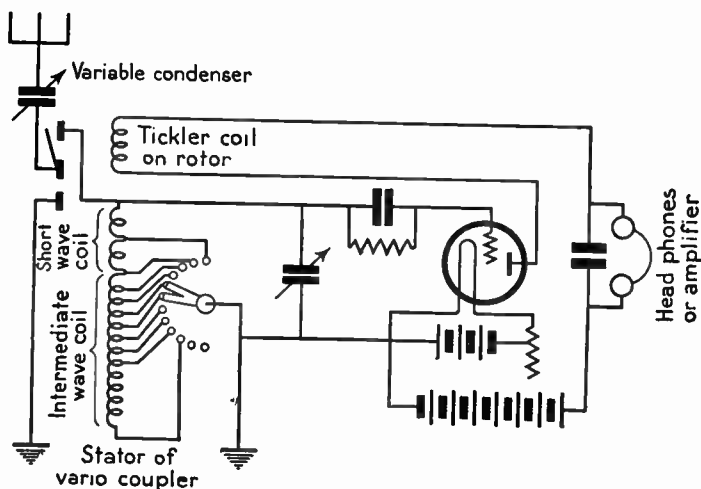


FIG. 60B.—Wiring diagram of receiver with a variocoupler and 12-section bank-wound inductance coil.

pipe, connect the other end of this to the + electrode of the A battery and connect this end also to one of the terminals of the filament. This done connect the other terminal of the filament to one post of the rheostat and the other post of this to the — or negative side of the A battery.

To the + electrode of the A battery connect the — or zinc pole of the B battery and connect the + or carbon pole of the latter with one post of the fixed .001 microfarad condenser. This done connect one terminal of the tickler coil which is on the rotor of

the variocoupler to the plate of the detector and the other terminal of the tickler to the other post of the .001 condenser and around this shunt your headphones. Or if you want to use one or more amplifying tubes connect the circuit of the first one, see *Fig. 50*, to the posts on either side of the fixed condenser instead of the headphones.

A Long-Wave Receiving Set.—The vivid imagination of Jules Verne never conceived anything so fascinating as the reception of messages without wires sent out by stations half-way round the world; and in these days of high power cableless stations on the five continents you can listen-in to the messages and hear what is being sent out by the Lyons, Paris, and other French stations, by Great Britain, Italy, Germany and even far-off Russia and Japan.

A long-wave set for receiving these stations must be able to tune to wavelengths up to 20,000 meters. Differing from the way in which the regenerative action of the short-wave sets described in the preceding chapter is secured, and which depends on a tickler coil and the coupling action of the detector in this long-wave set, this action is obtained by the use of a tickler coil in the plate circuit which is inductively coupled to the grid circuit and this feeds back the necessary amount of current. This is a very good way to connect up the circuits for the reason that: (1) the wiring is simplified, and (2) it gives a single variable adjustment for the entire range of wavelengths the receptor is intended to cover.

The Parts and How to Connect Them.—The two chief features as far as the parts are concerned

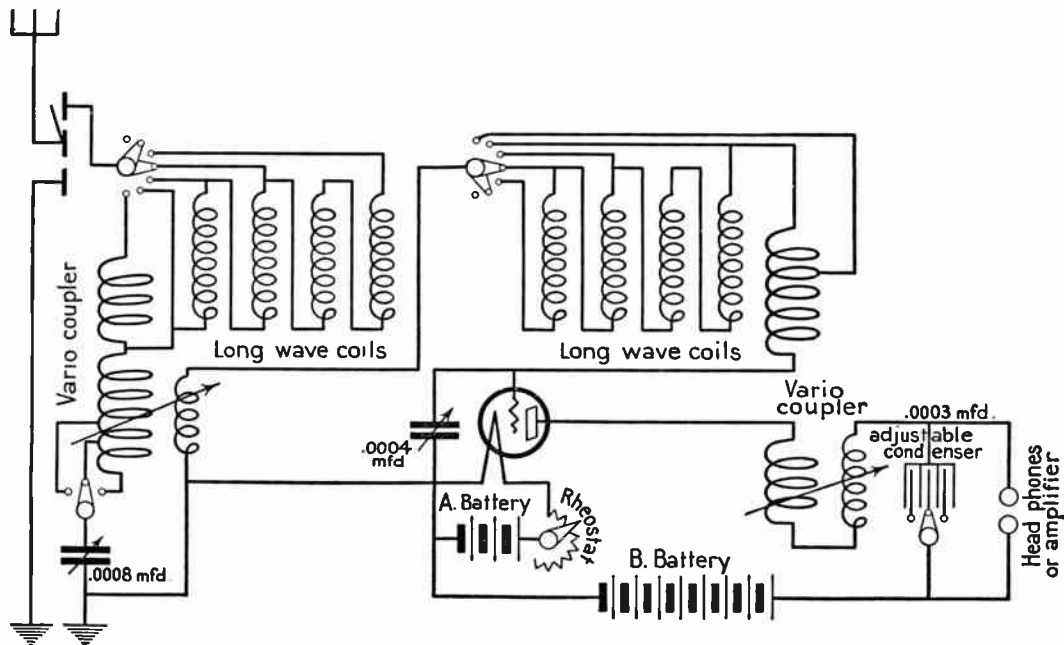


FIG. 61.—Wiring diagram of long-wave receiver using variocouplers and eight bank-wound inductance coils.

of this long-wavelength receiving set are (1) the *variable condensers*, and (2) the *tuning inductance coils*. The variable condenser used in series with the aerial wire system has 26 plates and is equal to a capacitance of *.0008 mfd.* which is the normal aerial capacity. The condenser used in the secondary coil circuit has 14 plates and this is equal to a capacity of *.0004 mfd.*

There are a number of inductance coils and these are arranged so that they can be connected in or cut out and combinations are thus formed which give a high efficiency and yet allow them to be compactly mounted. The inductance coils of the aerial wire system and those of the secondary coil circuit are practically alike. For wavelengths up to 2,200 meters *bank litz-wound coils* are used and these are wound up in 2, 4 and 6 banks in order to give the proper degree of coupling and inductance values.

Where wavelengths of more than 2,200 meters are to be received honeycomb coils are used, and are especially adapted for medium as well as long wavelengths. These various coils are cut in and out by means of two five-point switches which are provided with auxiliary levers and contactors for *dead-ending* the right amount of the coils. In cutting in coils for increased wavelengths, that is from 10,000 to 20,000 meters, all of the coils of the aerial are connected in series as well as all of the coils of the secondary circuit. The connections for a long-wave receptor are shown in the wiring diagram in *Fig. 61*.

CHAPTER XIII

HETERODYNE OR BEAT LONG-WAVE TELE- GRAPH RECEIVING SET

ANY of the receiving sets described in the foregoing chapters will respond to either: (1) a radio telegraph transmitter that uses a spark gap and which sends out periodic waves, or to (2) a radio telegraph or telephone transmitter that uses an arc or a vacuum tube oscillator and which sends out interrupted or modulated continuous waves. To receive radio telegraph signals, however, from a transmitter that uses an arc or a vacuum tube oscillator and which sends out continuous waves, an *oscillating* regenerative receiving set or a similar arrangement must be used so that the continuous waves will be broken up into groups of audio frequency.

There are four different ways employed at the present time to break up the continuous waves of a radio telegraph transmitter into groups and these are: (a) the *heterodyne*, or *beat*, method, in which waves of different lengths are impressed on the received waves and so produces beats; (b) the *tikker*, or *chopper* method, in which the high-frequency currents are rapidly broken up; (c) the *variable condenser* method, in which the movable plates are made to rapidly rotate; (d) the *tone wheel*, or *frequency transformer*, as it is often called, and which is really

a modified form of and an improvement on the tikker. The heterodyne method will be described in this chapter.

What the Heterodyne or Beat Method Is.—The word *heterodyne* was coined from the Greek words *heteros* which means *other*, or *different*, and *dyne* which means *power*; in other words it means when used in connection with a radio receiver that another and different high-frequency current is used besides the one that is received from the sending station. In music a *beat* means a regularly recurrent swelling caused by the reinforcement of a sound and this is set up by the interference of sound waves which have slightly different periods of vibration as, for instance, when two tones take place that are not quite in tune with each other. This, then, is the principle of the heterodyne, or beat, receptor.

In the heterodyne, or beat method, separate sustained oscillations, that are just about as strong as those of the incoming waves, are set up in the receiving circuits, and their frequency is just a little higher or a little lower than those that are set up by the waves received from the distant transmitter. The result is that these oscillations of different frequencies interfere and reinforce each other when *beats* are produced, the period of which is slow enough to be heard in the headphones, hence the incoming signals can be heard only when waves from the sending station are being received. A fuller explanation of how this is done will be found in *Chapter XVIII*.

The Autodyne or Self-Heterodyne Long-Wave Receiving Set.—This is the simplest type of heter-

odyne receptor and it will receive periodic waves from spark telegraph transmitters or continuous waves from an arc or vacuum tube telegraph transmitter. In this type of receiver the detector tube itself is made to set up the *heterodyne oscillations* which interfere with those that are produced by the incoming waves that are a little out of tune with it.

With a long-wave *autodyne*, or *self-heterodyne* receptor, as this type is called, and a two-step audio-frequency amplifier, you can clearly hear many of the stations of Europe and others that send out long waves. For receiving long-wave stations, however, you must have a long aerial — a single wire 200 or more feet in length will do — and the higher it is the better will be the signals. Where it is not possible to put the aerial up a hundred feet or more above the ground, you can use a lower one and still get messages in *International Morse Code* fairly strong.

The Parts and Connections of an Autodyne, or Self-Heterodyne, Receiving Set.—For this long-wave receiving set you will need: (1) one *vario-coupler* with the primary coil wound on the stator and the secondary coil and tickler coil wound on the rotor, or you can use three honeycomb or other good compact coils of the longest wave you want to receive, a table of which is given in *Chapter XII*; (2) two .001 mfd. variable condensers; (3) one .005 mfd. variable condenser; (4) one .5 to 2 megohm grid leak resistance; (5) one vacuum tube detector; (6) one *A* battery; (7) one rheostat; (8) one *B* battery; (9) one potentiometer; (10) one .001 mfd. fixed condenser and (11) one pair of headphones. For the two-step am-

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plifier you must, of course, have besides the above parts the amplifier tubes, variable condensers, batteries, rheostats, potentiometers and fixed condensers as explained in *Chapter VIII*. The connections for the autodyne, or self-heterodyne, receiving set are shown in *Fig. 62*.

The Separate Heterodyne Long-Wave Receiving Set.—This is a better long-wave receiver than the

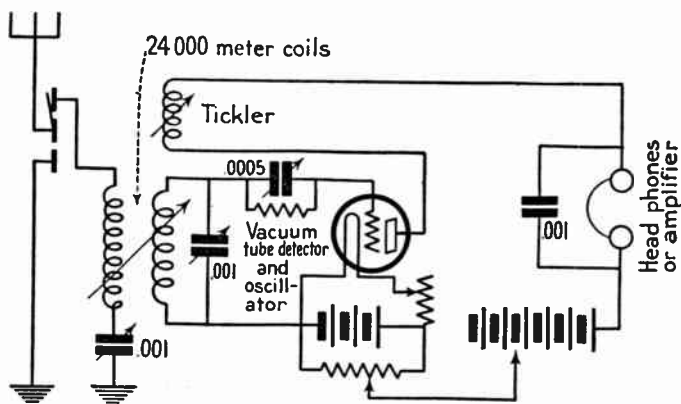


FIG. 62.—Wiring diagram of long-wave Autodyne or self-heterodyne receiver.

self-heterodyne set described above for receiving radio telegraph signals sent out by a continuous long-wave transmitter. The great advantage of using a separate vacuum tube to generate the heterodyne oscillations is that you do not have to detune the detector oscillation circuit to obtain the beat note. At high frequencies this effect is not noticeable, but at low frequencies it may cause a marked decrease in the strength of the signals.

The Parts and Connections of a Separate Heterodyne Long-Wave Receiving Set.—The parts required for this long-wave receiving set are: (1) four honeycomb or other good compact inductance coils of the longest wavelength that you want to receive;

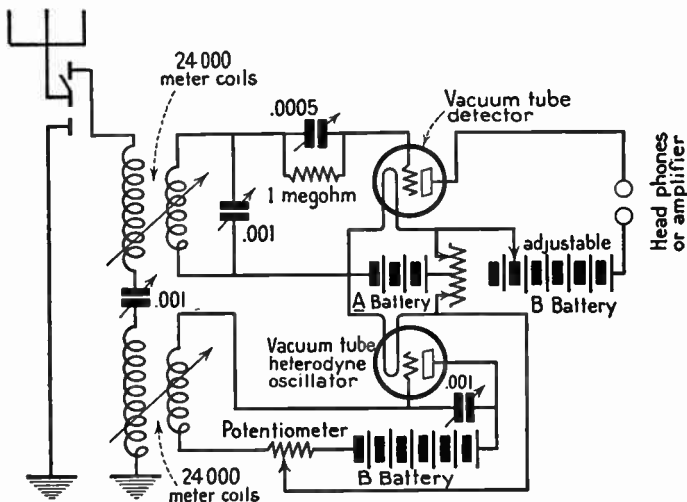


FIG. 63.—Wiring diagram of a separate heterodyne long-wave receiving set.

(2) three .001 mfd. variable condensers; (3) one .0005 mfd. variable condenser; (4) one 1 megohm grid leak resistance; (5) one vacuum tube detector; (6) one *A* battery; (7) two rheostats; (8) two *B* batteries, one of which is supplied with taps; (9) one potentiometer; (10) one vacuum tube amplifier,¹ for setting up the heterodyne oscillations; (11) a pair of headphones and (12) all of the parts of a two-step amplifier as

¹ The amplifier tube in this case is used as a generator of oscillations.

detailed in *Chapter VIII*, that is if you are going to use amplifiers. The connections are shown in *Fig. 63*.

In using either of these heterodyne receivers with gas content tubes be sure to adjust carefully the *B* battery by means of the potentiometer as the sensitiveness of the detector depends largely on the voltage impressed on the plate and especially must you do so when you exchange a new for an old detector tube.

CHAPTER XIV

A 245 PUSH-PULL RADIO AND PHONOGRAPH AMPLIFIER

It is conceded by nearly everyone to-day that radio broadcasting is one of the greatest sources of entertainment that has as yet been devised. However, like everything else it has its drawbacks. One of the most discussed of these is the fact that certain kinds of entertainment are not always available when they are desired. Then we fall back on the phonograph.

As in other methods of sound reproduction, the phonograph recently has undergone a radical change, and this change for the better has come through the radio art. Audio-frequency amplifiers and loud speakers are now necessities in the phonograph field, and in this chapter there is described an amplifier that may be used with either a phonograph or a radio receiver.

The designing of an all-purpose power amplifier and power-supply unit is not an easy task, when there is taken into consideration the fact that in order to obtain satisfactory results under all conditions proper impedance relations must be maintained. Let us consider the input circuit. The primary impedance of the usual input transformer is unsuited for use in direct connection with a phonograph pick-up.

It will be noticed that when the switch is in the "P" position, both the plate of the detector tube and the "B" supply lead are disconnected from the primary of the transformer, T. When the switch is in the "R" position, the pick-up is in an open circuit.

Another interesting feature of this amplifier apparatus is the output pushpull transformer, T2. It will be noticed that there are two secondary windings. The winding, M, is of high impedance and matches the impedance of the average electromagnetic loud speaker. The winding, D, is of low impedance and is for use in connection with electrodynamic speakers. This second winding eliminates the use of a separate impedance-matching transformer in the moving-coil circuit of the dynamic speaker. Obviously if the dynamic speaker has its own impedance matching transformer, it should be connected to the winding, M, of the transformer, T2.

The Power-Supply Unit.—In order to employ the new a-c. tubes, that are in almost universal use and which have been found to give excellent results in amplifiers of this type, a special power transformer is required to supply the power for the filaments and plate supplies.

The power transformer, T3, has five windings: the primary winding, connecting to the 110-volt a-c. light socket; a 2.5-volt filament winding to supply filament current to the receiver, if so desired; another 2.5-volt filament winding to supply the filaments of the two 245 amplifier tubes in the output and the 227-tube; a 5-volt winding supplying the filament of the 280 full-wave rectifier, and a high-

voltage winding, providing a maximum of 250 volts at the output, under normal conditions.

It will be noticed that all the filament heater windings have center taps and therefore, it is unnecessary to employ center-tapped resistances to balance out the hum.

The filter system of the power unit is made up of two filter chokes, Ch., Ch. and the high-voltage filter condensers, C, C1 and C2, with the capacities indicated in the diagram. These three condensers, as well as the condensers C3, C4, C5 and C6, are all contained in a single condenser block. The two filter chokes, Ch. Ch., are in a separate case.

The condensers, C3, C4 and C5, bypass the taps on the voltage divider resistance, R2, which supplies "B" voltage for the amplifier tubes as well as those in the receiver. Condenser C6 bypasses the 800-ohm resistor, R1, which provides the proper "C" bias for the grids of the 245-tubes. This resistor, as well as all the condensers, terminate at the point CT, which is the common terminal, or "B minus." The condensers are actually connected together inside the condenser block and there is but one common terminal from this unit. The two exceptions are the low-voltage condensers, C7 and C8, which can be seen mounted together on the baseboard in the illustration of *Fig. 65*.

The switch, A, is in one of the primary leads of the power transformer, T3, and may be any form of a 110-volt snap switch. This switch, of course, turns on and off both the amplifier and receiver, providing the receiver obtains its power from this unit. It is

sometimes necessary to employ in the 110-volt line a voltage regulator, which keeps the line voltage from varying more than about 2%. This is connected in the same lead as the switch A.

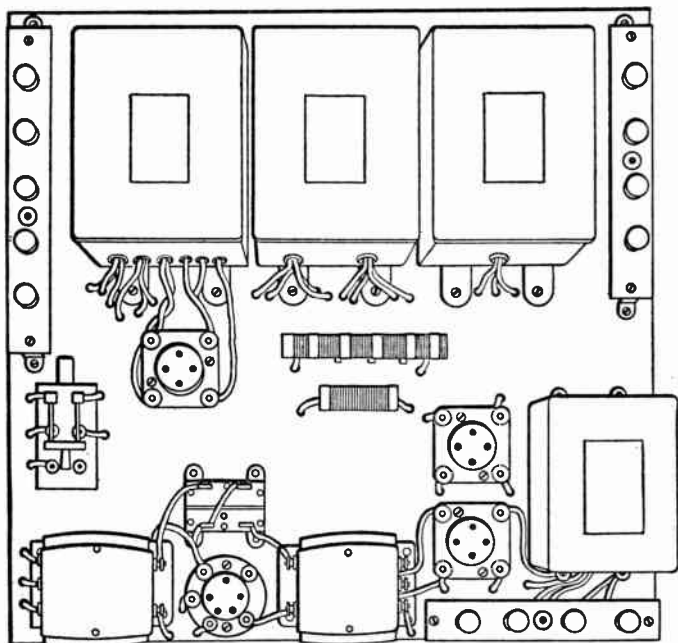


FIG. 65.—The general layout of apparatus for the radio and phonograph amplifier.

List of Parts Required.—The following are the parts needed for the construction of this power amplifier:

- 1 first stage a-f. transformer (T)
- 1 input pushpull transformer (T1)
- 1 output pushpull transformer (T2)
- 1 power transformer (T3)

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- 1 filter choke unit (Ch., Ch.)
- 1 condenser unit (C, C1, C2, C3, C4, C5, C6)
- 2 1mf. fixed condensers (C7, C8)
- 1 2000-ohm grid bias resistor (R)
- 1 800-ohm resistor (R1)
- 1 13,000-ohm tapped resistor (R2)
- 1 DPDT switch (SW)
- 3 4-prong sockets
- 1 5-prong socket
- 1 UY-227 tube
- 2 UX-245 power tubes
- 1 UX-280 full-wave rectifier tube
- 1 binding post strip 8"x1"x3/16"
- 2 binding post strips 7"x1"x3/16"
- 13 binding posts
- 1 veneer or bakelite baseboard, 15"x15½"x½"
- 4 rubber feet for baseboard
- Hookup wire and twisted wire, the latter for filaments
- 1 110-volt snap switch
- 1 phonograph pick-up.

There is not a great deal that can be said about the wiring of the amplifier, as most of the details can be gathered from the accompanying illustrations. The major portion of the wiring is run on the under side of the baseboard, which is raised by the four rubber feet.

Keep all the twisted filament leads well away from, or at right angles to grid and plate leads. Likewise see that all grid and plate leads are well separated. The parts should be so mounted on the baseboard that all leads are as short as possible, giving most consideration to the grid leads. It is well to follow the general plan indicated in the illustrations, but there is nothing against another arrangement, pro-

viding the changes do not alter the wiring scheme to any great extent.

The illustration of *Fig. 65* shows the general position of most of the parts. At the back of the baseboard are mounted, from left to right; the power transformer, T3; the condenser block, containing the high-voltage condensers, C, C1, C2, C3, C4, C5 and C6; and the filter choke unit, Ch., Ch.

The UX-280 rectifier tube is mounted directly in front of the power transformer case. The 245-tubes are mounted directly to the left of the pushpull output transformer, T2, which is at the extreme right front of the baseboard. The 227-tube is placed between two of the transformers; the one to the left of the tube socket is the input audio unit, T, and the one to the right is the input pushpull transformer, T1.

The binding post strip to the right and front of the baseboard carries the output terminals, there being two each for the magnetic and dynamic type speakers.

Referring to the illustration of *Fig. 65* the two bypass condensers, C7 and C8, are mounted directly behind the 227-tube socket. The 2000-ohm grid bias resistor is in the form of a strip and does not show up clearly in the illustration, but is connected from the cathode post on the 227 socket to the "-A" terminal of the first-stage a-f. transformer. The voltage-divider resistor, R2, can be seen in front of the condenser block and in front of this resistor unit is the 800-ohm "C" bias resistor, R1, which provides the proper bias for the two 245-tubes.

The binding post strip at the left of the baseboard

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carries a portion of the external connection terminals. They are, from top to bottom: the two 2.5-volt filament terminals, detector plate connection, and the two terminal connections for the pick-up unit. The binding post strip mounted on the right-hand side of the baseboard carries the plate voltage

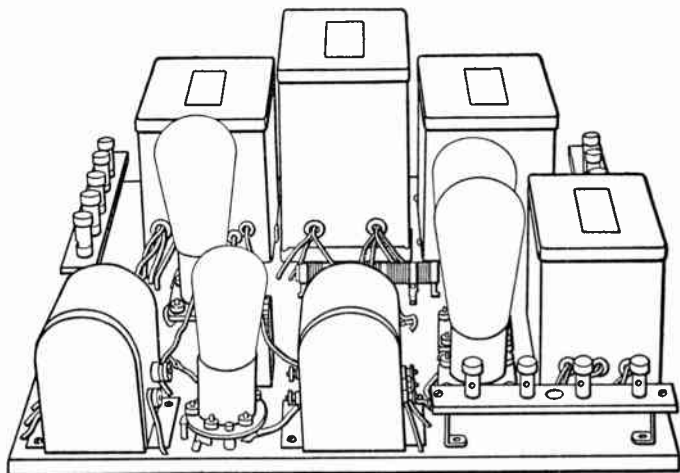


FIG. 66.—The amplifier with tubes in their sockets, these being from left to right, UX-280, UY-227, and the two 245 power tubes.

terminals. The top post is *B* plus 135, *B* plus 90, *B* plus 45 and the last post, *B* minus.

The double-pole, double-throw switch, SW, is seen mounted to the left of the 280-tube socket. In the event that the power amplifier is mounted inside a cabinet, the five leads connecting to this switch may be brought out to the panel of the radio receiver or any other desirable position and the switch mounted within easy reach. The same holds true for the 110-volt snap switch.

CHAPTER XV

POWER DETECTION AND NEW RECEIVERS

It has been previously mentioned that the detector tube is the most important vacuum tube in a receiver's circuit, for if this tube is not functioning properly the results from the loud speaker will be below par. A great amount of study has been devoted to this portion of the circuit and the latest findings from the laboratory have been in the combination known as the *power detector*.

This new combination is not more sensitive than the detector circuits in use heretofore, but it is capable of handling more power, which in turn means better reproduction—and that is what we are seeking. This increase of power input to the detector tube has come about through the increased efficiency of the radio-frequency amplifiers that have been developed. More signal strength is being delivered to the detector tube and if this tube is incapable of rectifying this increase without distorting the signals, then the use of power detection becomes a necessity.

Heretofore the average receiver has had two stages of r-f. amplification, and as the gain, or amplification, per stage was of a fairly low order the detector tubes could deliver to the a-f. amplifier undistorted signals. Greater power input to the detector was a rarity, as the r-f. stages were more or less difficult to keep from oscillating.

With the advent of the screen-grid vacuum tubes this condition was changed. These tubes have a high amplification constant and, as has been explained previously, due to the reduction of the internal capacity, the circuits in which they are used are quite stable. Therefore, with a 201-A or 227-type tube connected in a common detector circuit, as shown in *Fig. 67, I*, the output would be greatly distorted, simply because the tube could not handle the amount of power put into it with any great degree of efficiency.

Now the best detector circuit is one that will pass on to the a-f. amplifier rectified signals with a minimum of distortion. The circuit that has been in use for quite awhile is shown in *Fig. 67, I*, and this is one of the best ways of rectifying low-powered signals. It has, however, two disadvantages. First, it has a tendency to lose the higher frequencies, which are most important, especially in music, as they comprise most of the overtones by which we distinguish the differences in musical instruments. And the second, which has been already mentioned, is its inability to handle loud signals without distortion.

It is not impossible to remedy these faults, but even so there will result a certain loss. For example the higher audible frequencies can be kept intact by reducing the capacity of the grid condenser, but this will in turn reduce the tube's ability to handle strong signals. If the resistance of the grid leak is lowered in order that the loud signals may be handled more efficiently, then the tube's ability as a rectifier of weak signals is lessened.

•

With the use of screen-grid tubes in the r-f. amplifier and the resultant great gain in signal

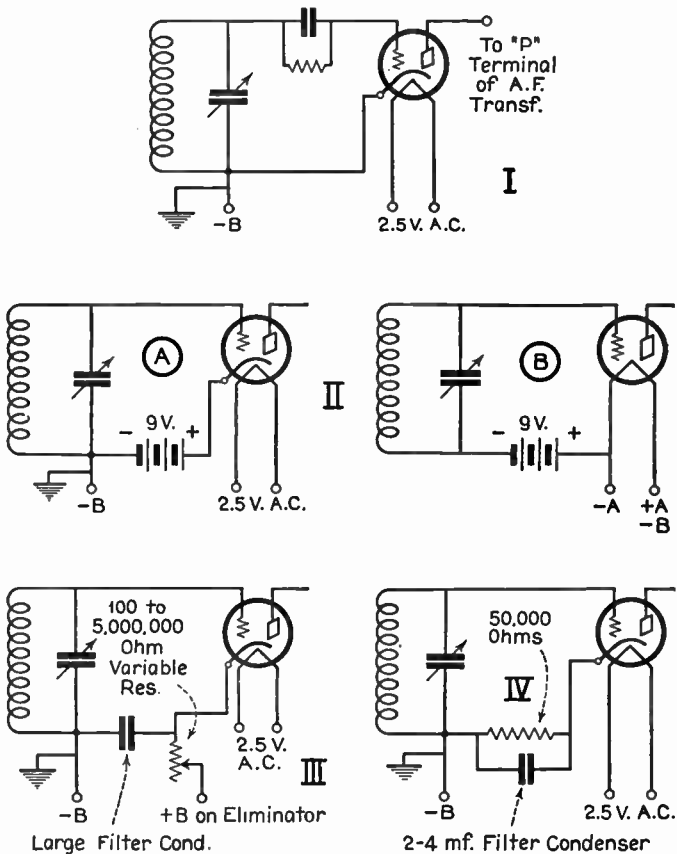


FIG. 67.—Different systems of power detection. The common method of detection is shown in I.

strength, it is possible to sacrifice some of the sensitivity of the detector circuit in order that more

power may be handled by it efficiently. This new circuit is called *plate rectification* or a power detector, and is illustrated in *Fig. 67*, II, *A* and *B*, the former being the connections for an a-c. tube of the UX-227 type and the circuit of *B*, that of a d-c. tube. It will be noticed that these circuits resemble an ordinary r-f. amplifier, but the tube acts as a rectifier because of the difference in ratio between the plate voltage and the grid bias, or "C" voltage. Also this action is due to the arrangement of the plate circuit, where a r-f. choke and bypass condenser gets rid of the radio frequencies that may be present in the detector's output.

Power Detector Circuits.—In *Figs. 67, II, III* and *IV* will be found different arrangements for power detection circuits. It will be noticed that the only difference between any of them and the circuit of *Fig. 67, I*, is that the grid condenser and grid leak have been removed and a grid bias applied in its place.

The amount of negative voltage applied to the grid of a power detector tube is roughly 10% of the value of the plate voltage. For instance, if the normal plate voltage requirement is 45 volts, then the grid bias should be 4.5 volts; if the plate voltage is 90, then 9 volts should be applied to the grid, and so on. If a two-stage audio-frequency amplifier is employed in the output of the power detector, it is unwise to use more than 90 volts on the plate of the detector, as this will pass more current than can be handled efficiently by this amplifier. However, if the power detector's output feeds directly into the power tube

(a UX-245 or UX-250) then 180 volts with 18 volts on the grid may be employed satisfactorily.

In the several diagrams of *Fig. 67* UX-227 type tubes have been shown as detectors, for more and more receivers that operate from alternating current are being manufactured. Let us consider each of the different methods of obtaining the grid bias.

In *Fig. 67, II*, the "C" bias is obtained from a separate "C" battery. This method is recommended to the reader, as this is the simplest and easiest of control. For optimum results it is sometimes necessary to connect a by-pass condenser across the leads of the battery. In this diagram the positive of the "C" battery is connected to the cathode (electron emitter) of the a-c. tube. In *B* of this diagram the positive of the battery is connected to the negative side of the filament and the negative side of the "B" battery to either the positive or negative filament battery, as called for in the original diagram of the receiver.

Fig. 67, III, shows the use of a variable resistor and a large filter condenser for obtaining the negative grid bias. This method can be used with good results only if the condenser has a large capacity and if the filter system of the "B" eliminator is of high quality.

The "C" bias in *Fig. 67, IV*, is obtained by the use of a fixed resistor, having a value of 50,000 ohms, across which is shunted a condenser between 2 and 4 mf. capacity. This resistor value will prove to be approximately correct no matter what amount of plate voltage is employed, as any increase in plate



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voltage will mean a correspondingly greater drop in voltage across this resistor resulting in an added negative bias on the grid.

New Receivers.—Now how will all this influence the design of receivers for the home? Mainly it will reduce the number of vacuum tubes needed to produce certain results. It has been mentioned previously that due to the development and widespread use of the screen-grid tube as a radio-frequency amplifier, an increased gain per r-f. stage has resulted. This then means that we can now obtain the same results with two tubes that hitherto three, or even more, tubes could accomplish only with great difficulty.

Then as the output of the power detector is greatly increased the number of audio-frequency amplifier stages can also be reduced. In fact, in many cases it is good practice to feed the detector output directly to the power-amplifier tube. However, if the last a-f. stage is a pushpull amplifier then a stage of transformer coupling is generally necessary to insure enough power to operate the output tubes efficiently.

From the foregoing it then appears that a receiver could be designed, that would furnish undistorted signals of sufficient volume for ordinary use, which would have two stages of radio-frequency amplification, using screen-grid tubes, a power detector and one stage of a-f. amplification using a power tube. These four tubes together with a rectifier tube, power transformer and filter system, would give a set entirely operated from the a-c. house mains and modern in every respect.

CHAPTER XVI

POWER-SUPPLY UNITS

WITH the advent of the rectifier tube radio reception took another great forward stride, for this sounded the death knell for plate batteries in the majority of cases. Several types of so-called *battery eliminators* were developed, but these in turn are used only on sets employing d-c. vacuum tubes.

Some of these eliminators used mechanical rectifiers for transforming the alternating into direct current, but the majority employed the rectifier tube. They consisted merely of a step-up transformer, which raised the 110-volt a-c. line voltage sufficiently high so that after allowing for the losses in the rectifier, there would be enough to supply the needs of the set's plate voltage requirements.

There are two types of rectifier tubes: (1) the filament type, and (2) the gaseous. The former type will be readily understood if the reader will carefully read the chapter dealing with vacuum tubes, for this type of tube is nothing more than the two-electrode valve of Fleming.

There are also two types of filament rectifiers: half-wave and full-wave. The former utilizes but one half of the a-c. wave and has but one plate. The full-wave rectifier has two plates and no part of the a-c. wave is lost. Half-wave rectifiers are known

as UX-216 or UX-281 and full-wave rectifiers as UX-213 and UX-280, the differences being in the amount of current that they pass. Special circuits must be used for these four tubes.

The function of the two plates in the full-wave rectifiers is as follows: when the filament is heated by the output from a separate winding on the power transformer large quantities of electrons are emitted.

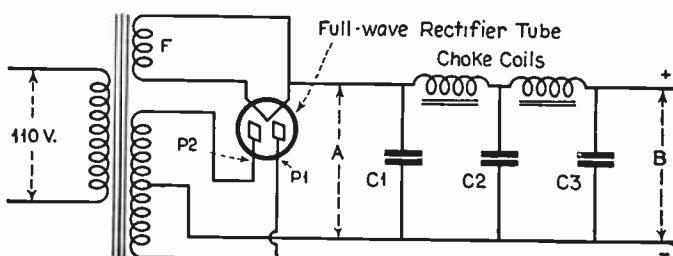


FIG. 68.—Diagram of a power-supply unit which is employed for changing a.c. to d.c. and smoothing out the latter.

Due to their being negative the electrons are attracted towards the plate of the tube, which is positively charged, which we will say is P1 in *Fig. 68*. Now when the other half of the wave is flowing in the secondary of the transformer P1 becomes negative and P2 positive, the electrons then going to the latter plate. In either case it will be seen that the secondary coil connected to the plates will have in addition to the high-voltage due to the transformer action a pulsating rectified current flowing in different directions at each half of the cycle. In order to use this pulsating current as a plate supply the secondary is tapped as shown. Therefore, in this lead from the

center tap of the secondary there is *current flowing in but one direction*.

At the point marked *A* in *Fig. 68* we therefore have a pulsating direct current. If we were to look at this voltage in an oscillograph it would appear as a series of humps and would be unfit to apply to the plates of the tubes in the receiver. Therefore, between the rectifier and the plates we have inserted

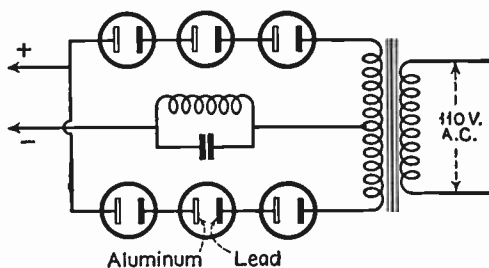


FIG. 69.—Connections of a chemical rectifier.

an electrical filter, which smooths out these humps. The action of this filter has been explained elsewhere. So at the point *B* an oscillogram of the voltage would appear as a straight line, showing that it would be satisfactory to use as plate voltage.

Chemical Rectifier.—In order to get a good plate supply for transmitting tubes, you can use (1) batteries, which are relatively expensive and do not have a long life; (2) a motor-generator set; (3) a rectifier tube and filter, as outlined above; or (4) a chemical rectifier and filter.

The chemical rectifier can be built with a little care, is cheap and is easy of construction. It consists of several rectifier cells formed by an electrode of

aluminum and an electrode of lead or some other metal immersed in a concentrated solution of borax ($\text{Na}_2\text{B}_4\text{O}_7$) and water. At ordinary temperatures such a cell permits the flow of current from the lead to the aluminum electrode, but for certain voltages checks the current flow in the opposite direction. See *Fig. 69*.

You will notice the words *certain voltages*. If these critical voltages are exceeded, which are determined by the nature of the solution (about 450 volts for borax), the thin film of gas on the aluminum electrode, which stops the current flow, breaks down and the current no longer has anything to stop it. If it is desired to use high voltages with a rectifier of this type several cells in series must be employed. If there is a rise in temperature in the cells this reduces the voltage at which the cell breaks down, therefore there must be sufficient solution to dissipate the heat generated and the surface of the electrodes must be of sufficient area.

In the following table will be found specifications for two sizes of chemical rectifiers for use with two 5- or 50-watt tubes:

| Power Watts | Normal d-c. Amperes | Number of Cells Per Bank | Voltage | Area of Elec- trodes | Solution Pint |
|----------------|---------------------------|--------------------------------|---------|----------------------------|------------------|
| 5 | 0.1 | 6 | 550 | 3/8" x 2" | 1/2 |
| 50 | 0.3 | 12 | 1100 | 3/4" x 3" | 1 |

To make the solution, dissolve as much borax as you can in cold water and use the clear liquid. The electrodes are prepared by cleaning with sandpaper

or scraping and then boiling them in a solution of caustic potash and scrubbing in order to remove every possible trace of grease. The electrodes are first shaped as shown in *Fig. 70* before cleaning.

After they have been placed in the solution to the proper depth, as indicated in the table above, pour about $\frac{3}{8}$ inch of oil on the electrolyte to prevent

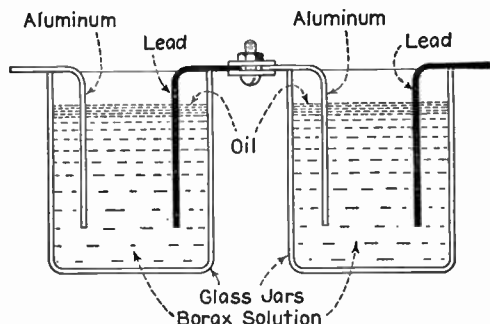


FIG. 70.—The construction of a chemical rectifier.

evaporation and to reduce the danger of an arc forming between the unimmersed portions of the aluminum electrode to the electrolyte. The oil should not be too heavy to stop the escape of the gas.

It is best to set up the jars, which may be of glass, in trays, which have been insulated from each other and from the ground by insulators. It is a safe precaution to coat the trays with paraffin and they should be kept dry.

CHAPTER XVII

HEADPHONES AND LOUD SPEAKERS

Radio Headphones.—A telephone receiver for a radio receiving set is made exactly on the same principle as an ordinary Bell telephone receiver. The only difference between them is that the former is made flat and compact so that a pair of them can be fastened together with a band and worn on the head (when it is called a *headset*), while the latter is long and cylindrical so that it can be held to the ear. A further difference between them is that the radio headphone is made as sensitive as possible so that it will respond to very feeble currents, while the ordinary telephone receiver is far from being sensitive and will respond only to comparatively large currents.

How a Bell Telephone Receiver Is Made.—An ordinary telephone receiver consists of three chief parts: (1) a hard-rubber, or composition, shell and cap; (2) a permanent steel bar magnet, one end of which is wound with a coil of fine insulated copper wire; and (3) a soft iron disk, or *diaphragm*, all of which are shown in the cross-section in *Fig. 71*. The bar magnet is securely fixed inside of the handle so that the outside end comes to within about $\frac{1}{32}$ of an inch of the diaphragm when this is laid on top of the shell and the cap is screwed on.

The ends of the coil of wire are connected with

two binding posts which are in the end of the shell, but are shown in the picture at the sides for the sake of clearness. This coil usually has a resistance of about 75 ohms, and the meaning of the *ohmic resistance* of a receiver and its bearing on the sensitiveness

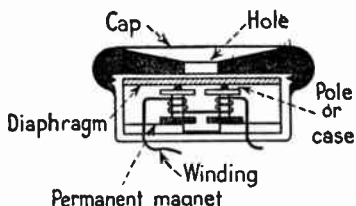
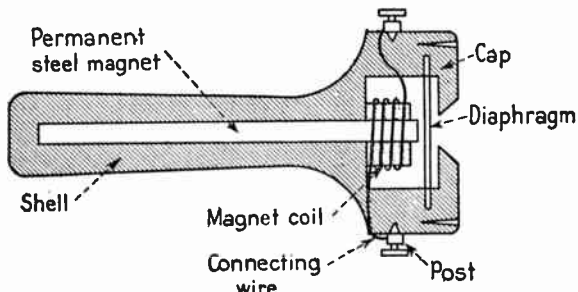


FIG. 71 (above).—The cross-section of a telephone receiver.

FIG. 72.—The cross-section of a bipolar type of receiver, which is in general use for radio work.

of it will be explained a little farther along. After the disk, or diaphragm, which is generally made of thin, soft sheet iron that has been tinned or japanned, is placed over the end of the magnet, the cap, which has a small opening in it, is screwed on and the receiver is ready to use.

How a Radio Headphone Is Made.—For radio work a receiver of the watch-case type is used and

nearly always two such receivers are connected with a headband. It consists of a permanent bar magnet bent so that it will fit into the shell of the receiver as shown in *Fig. 72*. The ends of this magnet, which are called *poles*, are bent up, and hence this type is called a *bipolar* receiver. The magnets are wound with fine insulated wire as before and the diaphragm is held securely in place over them by screwing on the cap.

About Resistance, Turns of Wire and Sensitivity of Headphones.—If you are a beginner in radio you will hear those who are experienced speak of a telephone receiver as having a resistance of 75 ohms, 1,000 ohms, 2,000 or 3,000 ohms, as the case may be; from this you will gather that the higher the resistance of the wire on the magnets the more sensitive the receiver is. In a sense this is true, but it is not the *resistance* of the magnet coils that makes it sensitive, in fact, it cuts down the current, but it is the *number of turns* of wire on them that determines its sensitiveness. It is easy to see that this is so, for the larger the number of turns the more often will the same current flow round the cores of the magnet, and so magnetize them to a greater extent.

But to wind a large number of turns of wire close enough to the cores to be effective, the wire must be very small and so, of course, the higher the resistance will be. Now the wire used for winding good receivers is usually No. 40, and this has a diameter of .0031 inch; consequently, when you know the ohmic resistance you get an idea of the number of turns of wire and from this you gather in a general way what the sensitivity of the receiver is.

A receiver that is sensitive enough for radio work should be wound to not less than 1,000 ohms (this means each ear phone), while those of a better grade are wound to as high as 3,000 ohms for each one. A high-grade headset is shown in *Fig. 73*. Each phone of a headset should be wound to the same resistance, and these are connected in series as shown. Where two or more headsets are used with one radio receiv-

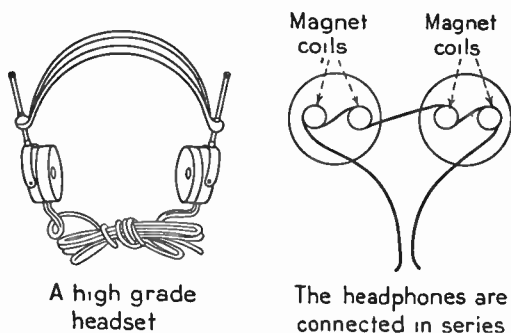


FIG. 73.—A radio headset and its connections.

ing set they must all be of the same resistance and connected in series, that is, the coils of one headset are connected with the coils of the next headset, and so on to form a continuous circuit.

The Impedance of Headphones.—When a current is flowing through a circuit, the material of which the wire is made not only opposes its passage—this is called its *ohmic resistance*—but a *counter-electromotive force* to the current is set up due to the inductive effects of the current on itself and this is called *impedance*. Where a wire is wound in a coil the impedance of the circuit is increased, and where

an alternating current is used the impedance grows greater as the frequency gets higher. The impedance of the magnet coils of a receiver is so great for high-frequency oscillations that the latter cannot pass through them; in other words, they are choked off.

How the Headphones Work.—As you will see from the cross-sections in *Figs. 71* and *72* there is no connection, electrical or mechanical, between the diaphragm and the other parts of the receiver. Now when either feeble oscillations, which have been rectified by a detector, or small currents from a *B* battery, flow through the magnet coils the permanent steel magnet is energized to a greater extent than when no current is flowing through it. This added magnetic energy makes the magnet attract the diaphragm more than it would do by its own force. If on the other hand, the current is cut off the pull of the magnet is lessened and as its attraction for the diaphragm is decreased the latter springs back to its original position. When varying currents flow through the coils the diaphragm vibrates accordingly and sends out sound waves.

About Loud Speakers.—The simplest acoustic instrument ever invented is the *megaphone*, which latter is a Greek word meaning *great sound*. It is a very primitive device and our Indians made it out of birch bark before Columbus discovered America. In its simplest form it consists of a cone-shaped horn and as the speaker talks into the small end the concentrated sound waves pass out of the large end in whatever direction it is held.

In the early days of radio broadcasting the meg-

aphone idea was employed in the loud speakers; that is, an ordinary watch-case receiver or pair of receivers was placed at the throat of a horn, which threw the sound in one direction, thus making it possible for a group of people to listen-in on one receiver.

However, it was soon discovered that in order to make the volume sufficiently loud so that a large number of people could hear with ease, it was necessary to add to the receiving set several stages of audio-frequency amplification, as the output of the detector tube was too low. When such amplification was used the resulting music was far from pleasing, as there was too great a current for the receivers and distortion resulted. Then engineers started on a quest for a loud speaker that would faithfully reproduce amplified music and speech.

To understand fully the different types of loud speakers that are to-day obtainable it might be well to consider for a moment the theory of reproducers in general. As has been explained previously sounds are reproduced from a phone by the to-and-fro movement of the metal diaphragm. Now the larger the distance that this diaphragm moves the greater will be the sound. In order to increase the volume we can therefore increase the movement of the diaphragm, keeping its size the same, or we can increase its size, so that it will set in motion a larger amount of air, and cut down on its movement.

Both these systems were tried, giving us the *paper diaphragm* or *cone* type of speaker, wherein is used the larger diaphragm, and the *dynamic* type, which uses a relatively small diaphragm and a rela-

tively great movement. Let us look at each of these different types.

The diaphragm of the cone type of speaker can be from 16 to 36 inches in diameter. To the apex of the cone is attached a slender stiff wire, which is known as the driving rod. This rod is attached to the armature of the unit, which is caused to move back and forth due to the changes in magnetic flux induced in the bar magnet by means of the two coils of fine wire wound about it and connected to the output of the receiving set.

The operation is as follows: due to the changes in the plate current of the last tube of the audio-frequency amplifier in the receiver, there is a corresponding change in the flux of the magnet. This causes the armature to move back and forth, which in turn moves the driving rod and so the diaphragm or cone. Thus we have the paper diaphragm moving in accordance with the various wave forms going through the set and setting in motion a large volume of air in the room which reaches the listeners' ears as sound waves.

The *electrodynamic* type of loud speakers produce even better results than the cone type and have the added advantage that the entire speaker's physical proportions are much smaller, making it easier to place in a cabinet or console. In general the diaphragm is also of heavy paper and is about 8 inches in diameter. The larger diameter of the cone, as may be seen in *Fig. 74*, is attached to a panel or baffle board by means of a ring of thin, flexible leather. This permits the cone to vibrate back and

forth with hardly any mechanical resistance. On the smaller diameter of the cone there is a coil of very fine wire, supported in a magnetic field set up by a field winding. This coil carries the signal current delivered by the audio amplifier and is acted

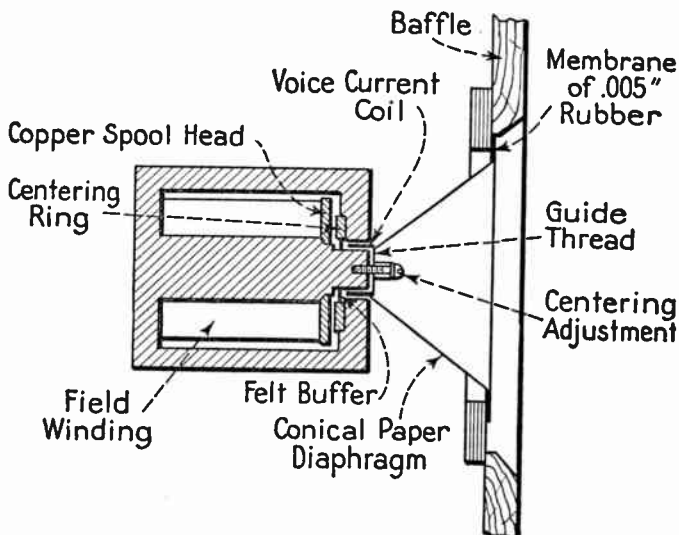


FIG. 74.—Cross-section of an electrodynamic loud speaker.

upon by the magnetic field moving the cone back and forth.

This field has to be excited by means of an outside source of current, which is supplied by a 6-volt storage battery or the 110-volt lighting circuit, a.c. or d.c. as the case may be.

It might be of interest to note in passing that this type of loud speaker is one generally used in connection with talking motion pictures. In order to

get away from troublesome echoes and other acoustical problems in theaters the sound waves are directed by means of large horns, having a throat equal in diameter to the diaphragm of the unit and a mouth several square feet in area. These speakers are employed in this work as they are capable of reproducing

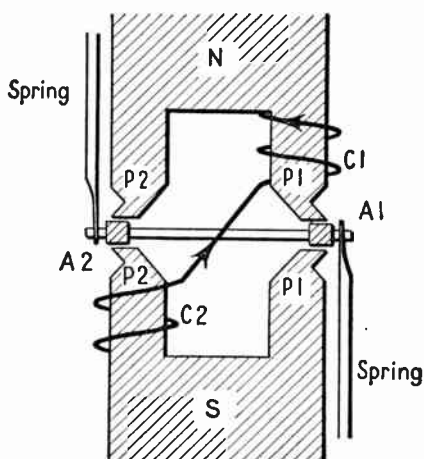


FIG. 75.—Sketch showing mechanism of the inductor dynamic speaker.

faithfully a large volume of music with minimum distortion.

One of the most interesting types of speakers that has as yet appeared is the inductor dynamic, developed by C. L. Farrand. This speaker combines the power and tone of the dynamic with the simplicity of the magnetic type of unit.

This unit has two horseshoe magnets and the moving mechanism, as may be seen from *Fig. 75*, is free

to float between the pole-pieces, giving to the cone a movement as much as 1/8 inch at low frequencies for maximum volume on a sufficient input. The principle is quite simple, being based on a changing magnetic flux, due to the signal current flowing through a pair of coils, C1 and C2, *Fig. 75*, acting on a pair of armature bars, A1 and A2, connected by tie-rods, each bar working between its respective pole-piece, P1 or P2. The rod that imparts the motion of the armature to the cone is connected to the piece holding A1 and A2 together. The cone is suspended from its baffle board in the manner described heretofore in the case of dynamic speakers.

Another type of loud speaker, the condenser speaker, is old in principle but new in application. More than sixty years ago in Europe the "singing condenser" was discovered, this being nothing more mysterious than a lightly rolled condenser made by placing a paper dielectric between two sheets of tin foil and using one electrode in opposition to the other sheet. When an alternating current was impressed across the electrodes the condenser would give forth a musical note depending upon the frequency of the impressed voltage.

This type of loud speaker functions because there is a mechanical stress generated between the two electrodes as they are electrically charged and when these charges vary, the electrodes are moved back and forth according to the variations of the current. If the two plates of this condenser have considerable size then the sounds emitted by the movement of the

electrodes will have sufficient volume to fill the requirements of a loud speaker.

Colin Kyle, who developed this speaker which has been named the Kylectron, employs a flexible dielectric between the two plates of the condenser. The rear plate of the speaker has a series of vents to secure the necessary freedom of motion to the dielectric, which is made of a substance that is nearly as elastic as rubber and has high insulating properties. The second plate of the condenser is a metallic-paint that is sprayed on the other side of the dielectric.

As this whole unit is only about $\frac{1}{8}$ inch in thickness and as it has no appreciable weight, it is easily used in consoles and in places where space is at a premium. These speakers have also been successfully employed in public address systems in large auditoriums and theaters.

A loud speaker is judged by the volume of air it can set in motion so that sound waves will be reproduced faithfully. In order to do this it must have a wide range of musical frequencies. Certain loud speakers have peaks—points at which certain notes are stressed more than others, thus giving the resulting sounds distortion.

A new loud speaker has been developed, which uses Rochelle salt crystals instead of the more usual magnets and coils. It was found quite a number of years ago that certain crystals convert electrical energy into mechanical energy and vice versa. Loud speakers are constructed from especially grown Rochelle salt crystals, by clamping three corners

of the crystal firmly and attaching to the fourth a rod which in turn is fastened to the apex of a diaphragm. When a varying voltage is impressed across the proper axis of the crystal the free corner will vibrate at the same rate as the impressed voltage. It is claimed by Dr. C. Baldwin Brush Sawyer, the inventor, that such loud speakers can reproduce music of the order of 9,000 cycles per second, which will include the great majority of the harmonics so essential for the faithful reproduction of music.

While on the subject of loud speakers it might be well to mention the fact that good results with enough volume to fill a room can not be obtained from a receiving set unless two stages of audio-frequency amplification are added after the detector. The subject of audio amplification has been considered in previous chapters.

There is little to say regarding the use of loud speakers. As the magnets used in the units are of a permanent type the current flowing through the coils will aid the magnetism when flowing in one direction and impede it if reversed. Generally the leads to the speaker are so marked that the proper lead can be connected to the positive side of the output. If not, then try the leads in reverse order to find the optimum results.

Nearly any loud speaker of a reputable make on the market to-day will give good results, the whole matter more or less depending on the amateur's pocketbook and the amount of volume desired.

CHAPTER XVIII

OPERATION OF VACUUM TUBE RECEIVERS

BEFORE trying to understand how a vacuum tube acts in a circuit, it is necessary to learn something about what makes it operate. In order to comprehend this, we must start at the very root of all matter—the *electron*.

We know that all matter exists in three forms: solids, liquids or gases. It is also known that any form of matter is not solid, but is composed of small parts of whatever material it may be, these small parts being called *molecules*. It is assumed that all molecules are composed of *atoms*, which are the chemical element particles. The kind of a molecule that will result depends on how many and what kind of atoms are grouped together.

Science also tells us that the atoms are composed of positive and negative *charges of electricity*, the number of these charges determining what chemical atom it is.

Every atom has a central core of *positive* particles of electricity, called *protons*, and around this *positive nucleus* are rotating *negative* electrical charges, named *electrons*. It is rather difficult to comprehend the lack of size of electrons, but an idea may be gained from the estimate that in a very tiny globule of copper, having a diameter of 1/100,000 of an inch, there are about twenty billion electrons. See *Fig. 76*.

The arrangement of electrons and protons in an atom may be compared to a miniature solar system, like that great one in which the planet on which we live is a part. We know that the Earth travels about the Sun once a year. In the same way in every atom one or more electrons are rapidly rotating

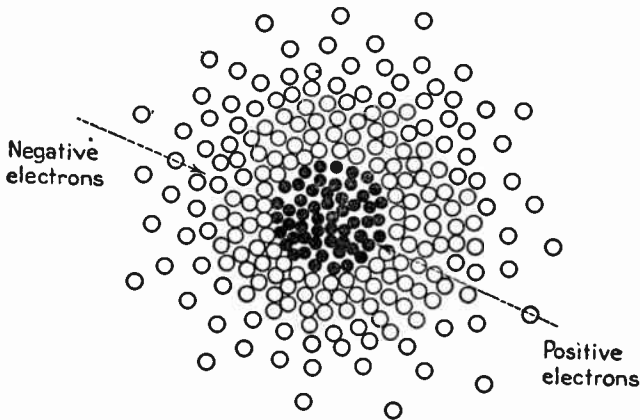


FIG. 76.—The grouping of electrons around the positive electrons (protons) in an atom.

about the positive nucleus, as the Earth does about the Sun. It is the number of protons and electrons in an atom that determine whether it be iron, gold, chlorine or hydrogen. The last-named element is the simplest in its makeup of the whole chemical table, as it has one proton for a positive nucleus and a single electron rotating about it; while uranium, the heaviest known element, has 92 protons in its nucleus.

The speed with which the electrons travel about the positive nucleus depends on the temperature. The hotter the substance of which the atom is a part,

the faster go the electrons. And, of course, the reverse is true, the colder the atom the slower the electrons travel, until at *absolute zero*, which is -273° C., theoretically all motion ceases entirely.

Ionization.—As long as all of the electrons remain within the influence of the positive nucleus of an atom its positive and negative charges are equalized and it will be therefore perfectly neutral, electrically speaking. When, however, one or more of its electrons are removed from it, and there are several ways in which this can be done, the atom will show a positive charge and in that state it is called a *positive ion*.

In other words, a *positive ion* is an atom that has lost some of its electrons, while a *negative ion* is one that has acquired some additional electrons, it being borne in mind that electrons are charges of *negative* electricity.

Therefore, ionization may be defined as *the addition or subtraction of one or more electrons from a neutral atom*.

The Relation of the Electron to Current Flow.—It seems advisable to explain the differences between the three types of current flow and how the electron acts in each one. These three currents are: Conduction, displacement and space or emission.

The fact has already been mentioned that in every atom there are one or more electrons whirling at a high speed about the positive nucleus, these electrons being kept in their orbits by magnetic attraction. Some of these electrons are attracted more strongly by the positive nucleus than others, which

are called *loose* or *free* electrons, as they are rather easily removed from the atom by means of an external electrical force.

Now we know that some metals are better conductors of electricity than others, which means that these conductors have atoms which contain more free electrons than the others. When an electrical force, such as a battery or generator, is applied to a wire, for example, these free electrons in the wire begin to move from one atom to another towards the source of the force. This movement of electrons is called *conduction current* or *electronic drift*.

It should be remembered that the atoms remain fixed in their positions in the wire; *it is only the electrons that move*. Also the direction of current is from *negative to positive*, as the electrons are the negative portion of the atom.

Displacement Current.—It is also a well-known fact that some materials, commonly called *insulators*, do not conduct current to any appreciable extent. It was explained previously that condensers were composed of two plates of a conducting material with an insulator between them.

We have learned just above that in a conductor there are many free electrons in the atoms composing the material; the opposite is true in an insulator. The atoms have few if any free electrons, so that when an electrical force is applied to the material the electrons will not jump from atom to atom and so no current will flow.

Although the electrons will not move from atom to atom, yet there is a definite force applied to them



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Dr. Vladimir Zworykin, holding the cathode-ray tube, which is used in the new radiovision receiver

so that they are moved slightly from their original places. Now in a condenser we have a conducting wire attached to each plate. When an electrical force is applied to the wires, there is a conduction current set up that sets in motion the electrons in the wire. These electrons travel along until they come in contact with the electrons of the insulator. As more electrons are coming from behind, the negative charge on the positive side of the insulator, or dielectric, is increased, so that the electrons in the dielectric are strained or pushed out of their regular places in their respective atoms. They will remain in this strained position, or as we say, the condenser maintains its charge, even after the electrical force that charged it is removed.

Now what happens when we discharge the condenser by bringing in contact the ends of the wires, which are connected to the two plates? The electrons that have been strained from their original positions within the atoms of the dielectric at once tend to return to their previous state of neutrality and so the electrons, that have been forced in, are now pushed out and are carried around through the connecting wire to the other plate of the condenser, which had been drained of its electrons to a certain extent. In other words, the whole system returns to a neutral state.

Therefore, the shifting of the electrons within the dielectric is called *displacement current*.

Space or Emission Current.—Under ordinary conditions existing in a copper or tungsten wire electrons will flow along easily, when a proper electri-

cal force is applied. However, it is difficult to remove these free electrons from the metal. If we change conditions somewhat we can make these free electrons jump from the surface of the metal out into space. We can increase the amount of current so that the temperature of the wire is raised until the wire becomes incandescent. Now the electrons of the wire will whirl about in their orbits more quickly and this increase of speed will also increase their orbits, or distances that they travel around the positive nucleus. These orbits will increase with the temperature and at a certain point the electrons will be traveling so fast that they will leave their atom and jump to another. This transfer from atom to atom will continue until the electron reaches one on the surface of the filament. When this occurs then the fast-moving electron jumps from the metal into space. This process of removing electrons from atoms is called *ionization by heat*, being different from *ionization by impact*, which occurs in the case of conduction current.

Now if we enclose the filament in a glass tube from which the air has been removed, and insert a metal plate to which a wire is connected, we can control this stream of electrons by giving the plate a positive charge, so that the electrons will be attracted to it. This stream of electrons between the filament and plate of a vacuum tube is called *space* or *emission current*. The source of electrons (the filament) is called the *cathode* and the plate, or destination of the negative charges of electricity, is called the *anode*.

The Two-Electrode Vacuum Tube.—We have just learned that when the filament of a vacuum tube is heated so that it glows, it emits electrons. As these electrons are charges of *negative* electricity they are attracted to the plate of the tube, which is charged *positively* by connecting it to the positive pole of a battery. This is what is meant by saying that the plate is positive with respect to the filament.

Now as the filament is hot and the plate is cold, the latter cannot emit electrons—it can only attract them, as stated above. Therefore, in the two-electrode tube *current passes in one direction only, i.e., from the filament to the plate.* In other words, we have a *direct or unidirectional current* flowing from filament to plate.

An alternating current is one that changes its polarity periodically, from positive to negative then positive again. The number of changes or cycles that the current undergoes per second is called *frequency*. In *Chapter IV* was pointed out this difference between radio-frequency and audio-frequency currents, that r-f. currents are those which the human ear cannot hear and, as the name implies, a-f. currents can be heard.

If we had an instrument called an oscillograph it would be possible to see an alternating or direct current. The former would have the appearance of a *sine wave*, illustrated in *Fig. 78A*. The halves of the wave above the horizontal line are considered to be positive and the lower halves negative.

If we connect a source of alternating current to the elements (the filament and plate) of a vacuum tube,

as well as the filament and plate batteries, so that we will have an electronic stream flowing, and looked at the output of the tube through an oscillograph we would find that there was a change in the appearance of the a-c. wave. Only the top halves of the wave would come through the tube. This is because during half the cycle (a cycle is one complete wave) the plate has a positive charge, which attracts the electrons emitted from the filament, and during the other half of the cycle, the plate is negatively charged so that it will repel the electrons and no current flows. Such an output from a tube is called *pulsating direct current*, as it is not a steady flow, such as is obtained from a dry cell battery.

Dr. James Fleming, of University College, London, discovered that a two-electrode vacuum tube could be used as a detector of radio-frequency currents, transforming them to currents that are audible to the human ear when a telephone receiver was connected in the output (between the plate of the tube and the plate battery).

The word "detector," although commonly used, is apt to mislead the reader. The action above described is really *rectifying*. At the present time the two-electrode vacuum tube is no longer used in a radio receiver as a detector; it is more efficient when used as a *rectifier* in the power units, about which more will be told later.

The Three-Electrode Vacuum Tube.—The two-electrode tube had many limitations as a detector, but with the addition of a third electrode, or *grid*, the vacuum tube was found to be the most efficient

detector yet discovered, and with a few minor changes it could be used for amplifying.

Dr. Lee DeForest in the early days of the present century discovered that if a third electrode, or element, were placed in the electronic stream between the filament and the plate and this grid, as it is called, be given a positive or negative charge, the number of electrons going to the plate from the filament could be controlled. In other words, the grid acts as a valve to the electronic stream, as it is possible to vary the relatively large plate current of the tube by very small charges on the grid.

The Action of the Grid.—Let us see how a three-element tube operates as a detector in a receiving circuit. Connected to the grid and the filament of the tube is the output of the detector circuit, consisting of a coil shunted by a variable condenser, so that the circuit can be tuned to resonance with the incoming signal. The signal current is at radio frequency and is alternating, that is, changing from positive to negative thousands of times per second.

As the grid is connected to this oscillating current, its polarity changes with the polarity of the r-f. current. Let us now follow one complete cycle through the tube and see how it affects the electron stream coming from the filament. See *Fig. 77*.

During half the cycle the grid has a positive charge. This charge in addition to the positive charge maintained on the plate, will attract more electrons that are being thrown off the filament in the direction of the plate. In other words, *when the grid has a positive charge, the plate current is increased*. Some electrons,

of course, strike the wire grid and are absorbed in the grid circuit, but the majority of them reach the

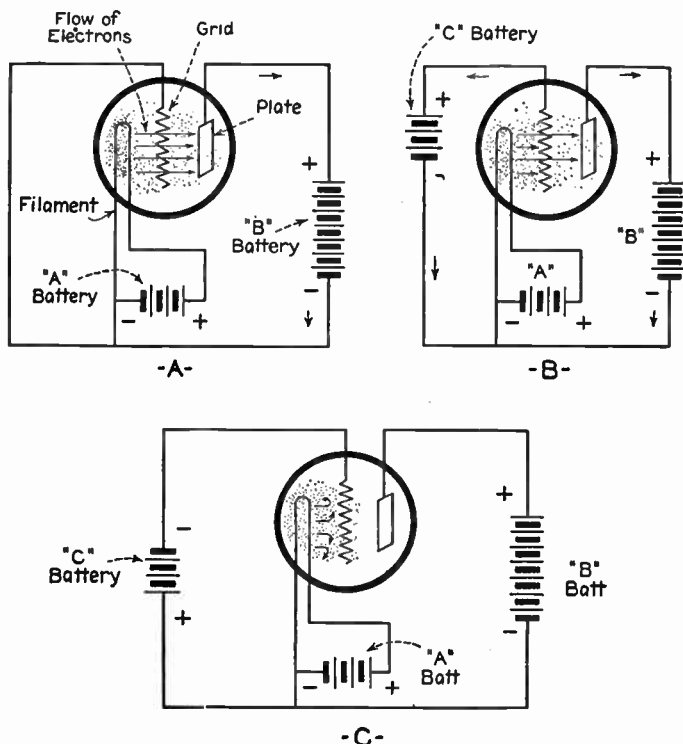


FIG. 77.—How the grid affects the electronic flow from filament to plate. A, no charge on grid; B, positive charge on grid, and C, negative charge on the grid.

plate through the relatively large spaces between the grid wires.

When the negative half of the wave charges the grid, then the reverse is true. As the electrons are negative, so the grid, having the same polarity, will

repel some of them back towards the filament and, therefore, fewer will reach the plate of the tube, thus reducing the plate current.

Summing up, the grid of a vacuum tube permits more or fewer electrons to reach the plate depending on whether the grid is charged positively or negatively. Also the degree of these charges must be taken into consideration, as the variations of the incoming signal currents to the tube are very slight, and it is on these minute changes that the efficiency of the tube as a detector depends.

How the Vacuum Tube Acts as an Amplifier.— If you connect up the filament and the plate of a three-electrode tube with the batteries and do not connect in the grid, you will find that the electrons which are thrown off by the filament will not get farther than the grid, regardless of how high the voltage is that you apply to the plate. This is due to the fact that a large number of electrons which are thrown off by the filament strike the grid and give it a negative charge, and consequently, they cannot get any farther. Since the electrons do not reach the plate the current from the *B* battery cannot flow between it and the filament.

Now with a properly designed amplifier tube a very small negative voltage on the grid will keep a very large positive voltage on the plate from sending a current through the tube, and conversely, a very small positive voltage on the grid will let a very large plate current flow through the tube. This being true, it follows that any small variation of the voltage from positive to negative on the grid and the other way

about will vary a large current flowing from the plate to the filament.

In the Morse telegraph the relay permits the small current that is received from the distant sending station to energize a pair of magnets, and these draw an armature towards them and close a second circuit when a large current from a local battery is available for working the sounder. The amplifier tube is a variable relay in that the feeble currents set by the incoming waves constantly and proportionately vary a large current that flows through the headphones. This, then, is the principle on which the amplifying tube works.

The Operation of a Simple Vacuum Tube Receiving Set.—A simple vacuum tube detector receiving set works thus: when the filament is heated it gives off electrons as previously described. Now when the electric waves impinge on the aerial wire they set up oscillations in it, and these surge through the primary coil of the loose coupled tuning coil, a diagram of which is shown in *Fig. 39*.

The energy of these oscillations sets up oscillations of the same frequency in the secondary coil, and these high-frequency currents, whose voltage is first positive and then negative, surge in the closed circuit, which includes the secondary coil and the variable condenser. At the same time, the alternating positive and negative voltage of the oscillating currents is impressed on the grid; at each change from + to - and back again it allows the electrons to strike the plate and then shuts them off; as the electrons form the conducting path between the

filament and the plate the larger direct current from the *B* battery is permitted to flow through the detector tube and the headphones.

Operation of a Regenerative Vacuum Tube Receiving Set.—By feeding back the pulsating direct current from the *B* battery through the tickler coil it sets up other and stronger oscillations in the secondary of the tuning coil when these act on the detector tube and increase its sensitiveness to a remarkable extent. The regenerative, or *feedback*, action of the receiving circuits used will be better understood by referring back to *Fig. 62*.

When the waves set up oscillations in the primary of the tuning coil their energy produces like oscillations in the closed circuit, which includes the secondary coil and the condenser; the alternating positive and negative voltages of these are impressed on the grid and these, as we have seen before, cause similar variations of the direct current from the *B* battery which acts on the plate and which flows between the latter and the filament.

This varying direct current, however, is made to flow back through the third, or tickler coil of the tuning coil and sets up in the secondary coil and circuits other and larger oscillating currents and these augment the action of the oscillations produced by the incoming waves. These extra and larger currents, which are the result of the feedback, then act on the grid and cause still larger variations of the current to the plate and hence of the *B* battery current that flows through the detector and the headphones. At the same time, the

tube keeps on responding to the feeble electric oscillations set up in the circuits by the incoming waves. This regenerative action of the battery current augments the original oscillations many times, and hence produces sounds in the headphones that are many times greater than where the vacuum tube detector alone is used.

Operation of the Short-Wave, Super-regenerative Receiving Set.—When an ordinary regenerative receiving set, as described above, reaches a certain point of amplification, the detector tube begins to set up oscillations, and this puts an end to further useful regeneration. Up to this critical point, and especially just before it is reached, the effects of regeneration are enormously increased, but they cannot go beyond it.

The reason for this is that the oscillation circuit has so small an effective resistance that after the initial energy of the feedback sets up the amplifying oscillations in the tube these oscillations continue to surge and with such persistency that the oscillations, which follow from the feedback, have very little effect upon them. The energy of the oscillations set up by the incoming waves is, naturally, less and, it follows, the signal, speech or music is weaker when this condition is reached, than when the effective resistance of the circuit is small enough to allow the current rectified by the detector tube to get back to the same value after each variation of the oscillations set up by the incoming waves.

Now the purpose of the super-regenerative system is to circumvent this limitation of the original re-

generative circuit so that amplification can go on beyond it, and this is the way it is done: in this new system the factors of the circuits are so arranged that the amplifying oscillations set up by the tube do not depend so much on the feedback oscillations as on those which the oscillator tube itself sets up. This is caused by alternating the values of positive and negative resistance from moment to moment; that is, an alternating positive and a negative resistance are set up by the oscillations of the oscillator tube.

The result is that while the initial, or first, oscillations set up by the incoming waves are amplified, as long as the negative resistance is larger than the positive resistance, the oscillations are instantly cut off by reversing these resistances, when the next incoming wave sets up fresh oscillations. In other words, the tube is kept from setting up oscillations when the critical point is reached, by changing the negative resistance to the positive and then changing them about the other way.

While an oscillator tube that generates oscillations of a frequency of about 15,000 cycles per second is used to change the resistances, it is possible to use several different kinds of circuits. The frequency of the oscillations set up by the tube for this purpose must be just high enough so that you cannot hear them surging in your headphones, and a frequency of 15,000 cycles is high enough to be beyond the limits of audibility.

If, now, you will turn back to *page 124* and look at the wiring diagram shown in *Fig. 54*, you will see that the first tube is the regenerative amplifying

tube, and that the positive and negative resistances of its plate circuit are constantly changed about by the second tube, which is the oscillation tube. After the low-frequency oscillating currents have been transformed by the audio-frequency transformer, they pass through a third tube, called the detector, which simply rectifies the currents, that is, it changes them into a pulsating direct current which will operate the headphones.

Operation of Autodyne and Heterodyne Receiving Sets.—At *A* in *Fig. 33* is shown a picture of two tuning-forks mounted on sounding boxes to illustrate the principle of electrical tuning. When a pair of these forks is made to vibrate exactly the same number of times per second there will be a condensation of the air and the sound waves that are sent out will be augmented. But if you adjust one of the forks so that it will vibrate 256 times a second, and the other fork so that it will vibrate 260 times a second, then there will be a phase difference between the two sets of waves, and the latter will augment each other 4 times every second and you will hear these rising and falling sounds as *beats*.

Now electric oscillations set up in two circuits that are coupled together act in exactly the same way as sound waves produced by two tuning forks that are close to each other. Since this is true, if you tune one of the closed circuits so that the oscillations in it will have a frequency of 1,000,000, and tune the other circuit so that the oscillations in it have a frequency of 1,001,000 a second, then the oscillations will augment each other 1,000 times every second.

Operation of Vacuum Tube Receivers 201

As these rising and falling currents act on the pulsating currents from the *B* battery which flow through the detector tube and the headphones you will hear them as *beats*. A graphic representation

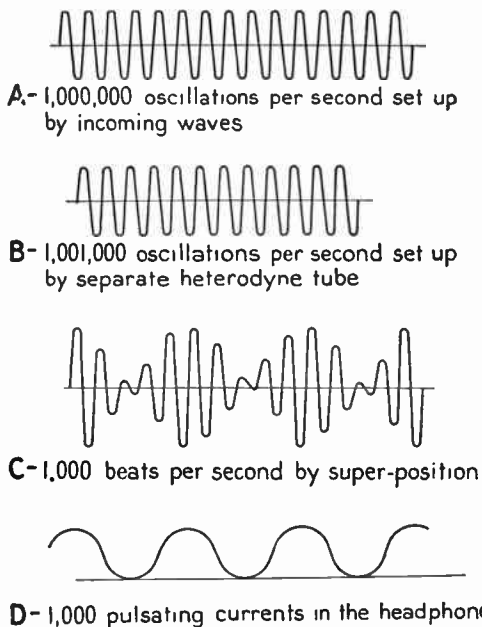


FIG. 78.—Illustrating the operation of a heterodyne receiver.

of the oscillating currents set up by the incoming waves, those produced by the heterodyne oscillator, and the beats they form is shown in *Fig. 78*. To produce these beats a receiver can use: (1) a single vacuum tube for setting up oscillations of both frequencies when it is called an *autodyne*, or *self-heterodyne* receptor, or (2) a separate vacuum tube for

setting up the oscillations for the second circuit when it is called a *heterodyne* receptor.

The Autodyne, or Self-Heterodyne Receiving Set.—Where only one vacuum tube is used for producing both frequencies, you need only a regenerative, or feedback receptor; then you can tune the aerial wire system to the incoming waves and tune the closed circuit of the secondary coil so that it will be out of step with the former by 1,000 oscillations per second, more or less, the exact number does not matter in the least. From this you will see that any regenerative set can be used for autodyne, or self-heterodyne, reception.

The Separate Heterodyne Receiving Set.—The better way, however, is to use a separate vacuum tube for setting up the heterodyne oscillations. The latter then act on the oscillations that are produced by the incoming waves and which energize the grid of the detector tube. Note that the vacuum tube used for producing the heterodyne oscillations is a *generator* of electric oscillations; the latter are impressed on the detector circuits through the variable coupling, the secondary of which is in series with the aerial wire as shown in *Fig. 79*.

Operation of the Superheterodyne Receiving Set. Major Armstrong devised the Superheterodyne receiver in his attempt to eliminate the inefficiency of radio-frequency amplification at short wavelengths and gain the immense amplification possible on the longer wavelengths. The only logical solution to the problem was to convert an incoming signal of a short wave to a longer wavelength of say

5,000 meters and then run it through a long-wave radio-frequency amplifier. This is exactly what he succeeded in doing.

You have learned from preceding chapters that a definite wavelength corresponds to a definite frequency and that the longer the wave the lower the frequency and vice versa. You have also learned

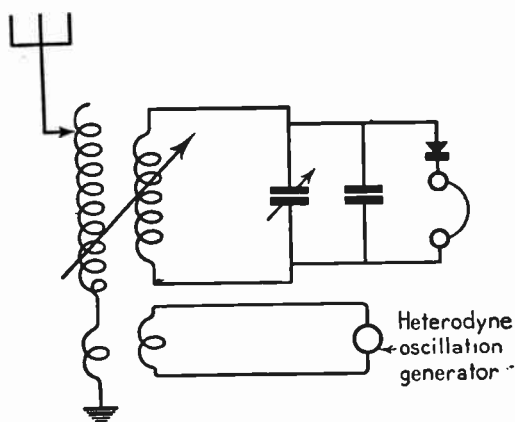


FIG. 79.—Diagram of a separate heterodyne oscillator.

that in order to receive continuous wave signals on a vacuum tube receiver it is necessary to employ the *autodyne* or *heterodyne* method, wherein a second frequency or wavelength is impressed on the receiving circuit so as to produce a *beat note* of the original signal that would be audible.

The separate heterodyne method is used in conjunction with the superheterodyne receiver, only instead of adjusting it so as to produce an audible beat note, a *radio-frequency* beat note is produced having a frequency not of approximately 1,000

cycles, but of the exact frequency that corresponds with the wavelength upon which the radio-frequency amplifying transformers are designed to work. In this way the incoming signal is actually converted to a longer wavelength, passed through the first detector (frequency changer) where the original radio-frequency wave is eliminated, then through the radio-frequency amplifiers, and finally through the second detector, where the signal is rectified and made into an audio-frequency.

CHAPTER XIX

NEW DEVELOPMENTS IN VACUUM TUBES

ONE of the most important contributions that science has made to civilization in recent years has been the vacuum tube. More and more uses are being found for this so-called "20th Century Aladdin's Lamp," which will be described in a later chapter, but here we are interested in some of the new types of vacuum tubes that are being employed in radio reception.

Alternating-Current Vacuum Tubes.—One of the greatest drawbacks heretofore to the layman, who knows nothing about the maintenance of a radio set, has been the care of the various batteries required to furnish power. Storage batteries are a necessity for receivers employing the 6-volt tubes, and the charging of this power supply has been a constant source of irritation to many people.

So the various manufacturers of tubes experimented for a number of years with a tube whose filament could be heated with alternating current, which could be stepped-down to any voltage necessary for efficient operation of the tubes. One of the first snags encountered was a hum in the loud speaker, when alternating current was employed, especially in the filament of the detector tube. Of course, rectified a.c. was also used as plate current.

Many different types of filaments were tried and finally one developed that reduced the hum in the receivers to an almost negligible quantity when used as a detector. In this tube the electron-emitting electrode (the cathode) is not the filament wire as in the UX-226, but a small-diameter circular sleeve that is coated with oxide and which surrounds the filament. When the filament is heated with alternating current the heat generated in it is radiated to and heats the cylinder, which emits electrons at a fairly low temperature. This type of a-c. tube is called the *cathode-heater*, and its designation is UY-227.

This tube has five prongs projecting from its base: two for the filament connections (2.5 volts, a-c.); one each for the grid and plate, and the fifth is connected to the electron-emitting cathode, to which the grid-return lead is connected. As the cathode must be heated by radiation from the glowing filament, there is a lapse of about 10 seconds before the electron stream is sufficiently large. This is, of course, not the case with the type of tubes in which the filament is the cathode.

In all a-c. receivers it will be noticed that in the secondary of the power transformer a special 2.5-volt winding has been added to supply the filament current for this type of tube. This current does not have to be filtered, as does the current supplied for the plate, which must be as much like the current from a battery as possible.

The UY-227 type vacuum tube is an excellent detector. When the tube is operating the entire



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The monitor in his control room where the proper volume is given to the music after it leaves the microphone and before it is put on the air.

surface of the cathode stays at a uniform potential with respect to the grid. This type of heater tube is therefore said to have an *equi-potential* cathode. This tube also is efficient in r-f. and a-f. amplifier stages.

The Screen-Grid Vacuum Tube.—This type of vacuum tube was first investigated in Germany by Schottky and later, Dr. A. W. Hull, of the General Electric Company's Research Laboratories, developed the screen-grid tube, UX-222, which is now in almost universal use as a radio-frequency amplifier.

In physical appearance the UX-222 resembles the UX-201A except that it has a metal cap at the top of the glass bulb. In *Fig. 80* will be seen the arrangement of the various elements and their relation to one another. There is a straight filament surrounded by the regular control grid, which instead of being a wire coil is made of a cylinder of coarse mesh. This control grid is connected to the metal cap at the top of the tube in order to reduce capacity effects. Around this grid is another grid of fine wire mesh connected to a metal disk, which extends out over the top of the plate. This last-mentioned element, which is quite a bit larger than the second grid, surrounds it. Around the plate is a cage-like

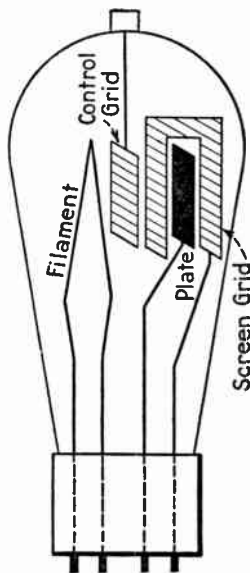


FIG. 80.

extension of the disk reaching below the bottom of the plate. This last-mentioned grid connects to the regular grid prong on the socket, the plate and filament being connected to their prongs in the usual manner. The filament is of thoriated tungsten and is rated at 0.132 amperes at 3.3 volts.

The question naturally arises, why is a tube like this necessary? The usual three-element tube when employed in a r-f. amplifier circuit needs a form of neutralizing or balancing to stop the generation of oscillations which are caused by the capacity between the grid and plate, this capacity being in the neighborhood of 8 mmf. in a 201-A type tube. There have been heretofore two general methods of preventing oscillations due to this small capacity—the *losser* method and the *Neutralization* method. In the former, sufficient losses were introduced into the circuit to keep the amplification down to a safe value, while in the latter, the feedback due to the internal capacity of the tube is balanced by a feedback of equal magnitude, but opposite in phase, introduced outside the tube. In the UX-222 this bothersome internal capacity is eliminated by the introduction of the fourth element, the screen grid.

How this capacity is practically eliminated may be understood better by reference to the following example. Between two parallel plates, P and G, in *Fig. 81A*, there exists a capacity which can be measured by the alternating current which flows through the ammeter A for some voltage measured by the voltmeter V. (These two plates represent the plate and grid elements of an ordinary three-

electrode tube and the dotted condenser symbol the capacity existing between them.) If another plate, SG (representing the screen-grid element), is placed between the other two (see *Fig. 81, B*) and connected as shown, the effect is now of two condensers in series, but the capacity between SG and P is shorted out of the circuit and the current indicated by the ammeter

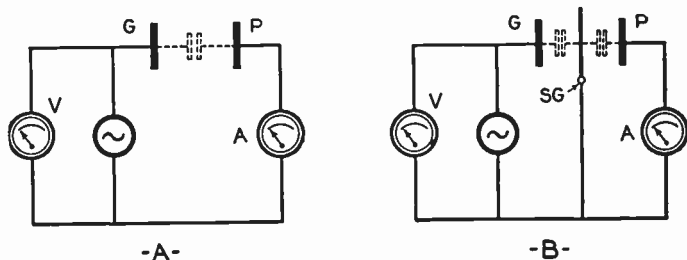


FIG. 81A and B.—Showing the condenser action caused by the insertion of a second element between the filament and plate in a screen-grid tube.

drops to zero. Therefore, we may say that the effective capacity between P and G has been reduced to zero by the addition of the plate SG connected as shown. It may be said that P is *shielded* or *screened* by SG.

When the UX-222 is employed as a r-f. amplifier the control grid is connected in the usual manner to the output of the coil and condenser, see *Fig. 51* and should have a negative bias of about 1.5 volts, which can be supplied by a C battery. As will be seen in the diagram the *positive* voltage necessary on the screen grid is between 22.5 and 45 volts, there being a r-f. choke coil placed in this lead. Ninety to 135 volts are necessary on the plate.

The r-f. transformers and their tuning condensers are usually placed in metal shields, which are grounded, this preventing coupling effects. The lead to the control grid at the top of the tube is enclosed in a metal sheath, which is also connected to ground. Because the tube is especially sensitive to external influences a metal shield is placed about the tube itself.

The screen-grid tube can be used in several ways. In a telephone transmitter it may be used as a modulator tube with one grid operated by the changes in radio-frequency currents and the other by the variations in the audio-frequency currents. It may be used as a *space-charge grid tube* in receivers where high amplification factors are a necessity. In this case the connections are different from those described heretofore. The screen grid is used as the control grid and has a negative bias of 1.5 volts. The control grid of the tube is employed as the space charge grid, having a positive bias of 22.5 volts. As this latter element is nearer the filament and has a positive bias with respect to the filament, it will neutralize to a certain extent the space charge and thereby permit a greater emission of electrons from the filament.

The screen-grid tube has been equipped with a heater and filament for operation with alternating current. It is of the cathode heater class and its designation is UX-224. The voltage for the heater filament is 2.5 with 1.75 amperes and its plate voltage (maximum value) is 180.

Rectifying Tubes.—During the last year the d-c. receiver has just about made its final bow, as all the

newer sets employ the a-c. tubes. With more and more power being required for receivers the power supply cost quite a considerable sum; not only the initial expense was high but also the maintenance. And it was also troublesome. Therefore the a-c. tube was a welcome feature.

This tube, however, introduced further difficulties. In order to make the receiver operate entirely from a source of 110 volts a-c. it was necessary to design a rectifier which would furnish the required d-c. plate voltage and current. It was a simple task to step-up the voltage to any given value in the power transformer, but to rectify this voltage properly and keep a sufficient amount of current to operate a multi-tube set was a great problem.

The UX-280 has two filaments in series heated by alternating current supplied by the secondary winding, of a power transformer S3, in *Fig. 82*. (Note: The other two windings, S1 and S2, are those supplying power for operation of the a-c. tubes in the amplifier and receiver.) Two plates are in the tube, each being connected to one end of the winding, S4, of the power transformer. The center tap of this winding represents the negative side of the d-c. supply.

As has been explained heretofore, when the filament of the UX-280 tube is heated electrons are emitted. Now we must imagine conditions during one complete cycle of the alternating current. When the positive half of the wave is induced in S4 we will assume that the plate P1 is charged positively. The stream of electrons will therefore be attracted to-

wards that plate and current will flow through it, around through the upper half of S4 and out through the center tap to the filter circuit. At this same instant the plate P2 is charged negatively and will repel electrons.

Now when the other half of this same wave strikes

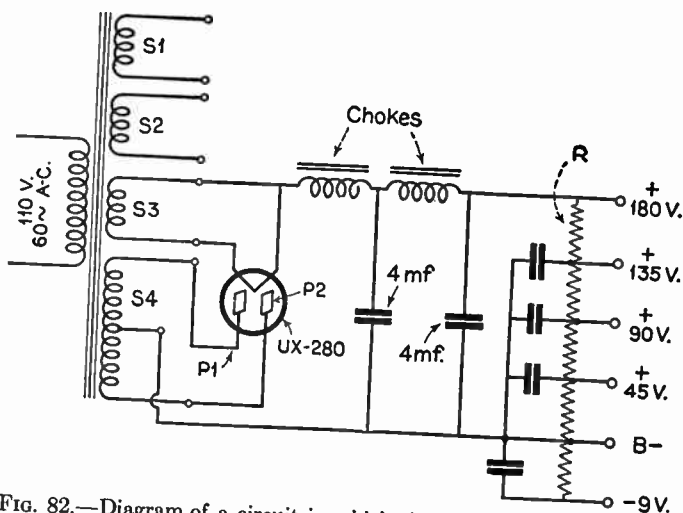


Fig. 82.—Diagram of a circuit in which the UX-280 rectifier transforms a.c. into pulsating d.c., which the filter smooths out.

S4 conditions will be reversed. P1 will be negative and P2 will have a positive charge. Therefore the stream of electrons will be attracted to the latter plate and the current will flow through the lower portion of S4 and out into the filter circuit through the center tap, as it did in the former case. Thus it may be seen that current always flows in the same direction through the center tap of the secondary S4.

The Operation of the Filter.—The function of the filter system shown in *Fig. 82* is to smooth out the pulsating direct current delivered from the rectifying tube, so that it will be as nearly like that delivered from a battery as is possible.

The two choke coils have a high self-inductance and their function is to keep the *current* flowing through the system unchanged. If the current fluctuates the magnetic lines of force produced about the windings of the chokes tend to induce a current that will buck the other and keep it constant. Also this counter e.m.f., set up within the choke will charge the large condensers shunted across them with a higher voltage. Therefore, whenever the rectifier's output lowers in value, the voltage of the output will be less than that at which the condensers are ordinarily charged and the condensers will discharge so that the line will come back to its normal condition.

This happens every cycle, as the output of the rectifier is not a smooth line but a series of humps. The action of the filter system smooths out these irregularities and delivers to the resistor, *R*, a current sufficiently unvarying so that the difference between it and the output from a battery is negligible.

The tapped resistor, *R*, is inserted in the circuit in order that a number of different voltages may be obtained for the various requirements of plate and grids in the receiver and amplifier. It is a simple matter to calculate the amount of resistance necessary to obtain the drop in voltage needed and to take a tap off at those particular points.

Power Tubes.—It is only recently that power tubes have been extensively used in radio receivers. These tubes are employed in the last audio-frequency stage and their function is to deliver the a-f. signals to the loud speaker with a relatively high current and with no distortion. Their type numbers are UX-210, UX-245 and UX-250, the two last having more or less taken the place of the 210 in receiving practice.

Power tubes have a *low* amplification factor, generally from 3.5 to 8, and their grid can handle large variations of voltage which are reproduced by the plate current without distorting the wave form of the impressed signal. If the voltage changes of the grid are large, as the signal varies from positive to negative, the grid will be overloaded and the current in the plate circuit will be robbed of its peaks. Therefore, the tube is distorting the signals delivered to it. It is these peak voltages that are important in the faithful reproduction of signals.

In appearance power tubes are similar to the 201-A type, except they are slightly larger. The requirements of their power supply will be found in the vacuum tube chart in the rear of the book. These tubes are also used in transmitters.

CHAPTER XIX-A

FURTHER DEVELOPMENTS IN VACUUM TUBES

IN the previous chapter some of the standard vacuum tubes were described—vacuum tubes such as are found in nearly every radio receiver. However, research laboratories have been doing a vast amount of experimentation on tubes and some of the latest developments will be explained below.

The Pentode.—Just as the addition of the screen grid was a step forward when it was added to the triode, so the adding of the suppressor¹ makes the tetrode (four elements) into a five-element tube (the pentode) that will do things that have not been done with the same ease before.

It will be remembered that when electrons collide with atoms the tendency is for them to dislodge an electron from the atom, if the first electron is traveling at sufficient speed. When the plate voltage is high in a tube the electrons move from the filament or the cathode to the plate at a high velocity and when they strike the plate, dislodge other electrons. In the ordinary triode these free electrons so dislodged do no particular harm, because there is no other positively charged body in the vicinity that they can affect. However, in the case of the screen-

¹ The "Suppressor" is similar to the screen grid in construction and is located between the screen grid and the plate.

grid tube, where the screen is at a positive potential with respect to the filament (cathode), this element offers a strong attraction for these free electrons and in some cases the plate current is reduced in strength because of them.

In order to remove these so-called secondary electrons from the path of the main electronic stream from the cathode to the plate, the suppressor is placed between the screen grid and the plate, it being usually connected to the cathode. This element is greatly negative with respect to the plate and so when the secondary electrons move out from

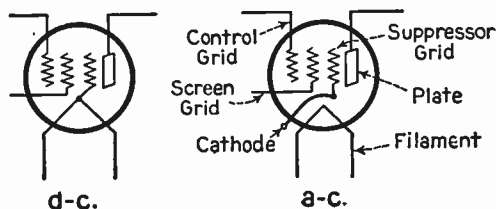


FIG. 82A.—The suppressor grid is connected to the cathode in the pentode tube, for the purpose of removing the secondary electrons.

the plate they encounter this negative charge and are diverted back again to the plate, where they cause no trouble.

Pentodes are used in two places at the present time and there is little doubt that as further experimentation is carried on, more uses will be found for them. Tubes such as the '33, '38, and '47 are used as power output tubes, where the suppressor element makes possible a large power output with a relatively large gain in voltage, because the voltage swing of

the regular grid (the control grid) can be made so large. Radio-frequency amplifier pentodes, the '34 and '39, use the suppressor as a means of obtaining a high-voltage amplification at moderate values of plate voltages. The schematic diagrams of the pentode tube for both d-c. and a-c. operation are shown in *Fig. 82A*.

The 2-Volt and 6.3-Volt Tubes.—In the early days of radio broadcasting most receivers were designed for tubes that operated with either dry cells or a storage battery as their source of filament heating power. Until the advent of the a-c. powered tube the bother of storage battery or dry cells was thought to be one of radio's necessary evils. Yet to-day a series of tubes are found that are especially designed for receiving their filament power from either of these two sources. This is because a relatively large proportion of the world is not serviced with alternating current and either the primary or secondary cells must be used if radio broadcasting is to be enjoyed.

The 2-volt tube, which has a filament consumption of 0.06 ampere, is designed to operate from either two dry cells in series or a single cell of a storage battery. The '30 tube can be employed either as a detector or amplifier; the '31 is a power amplifier, its filament current being 0.130 ampere; the '32 is a screen-grid tube best used as a radio-frequency amplifier tube; and the '33 is a power amplifier pentode. The other constants of these tubes will be found in the chart in the rear.

The 6.3-volt tube series was designed primarily for use in automobile receivers and in sets operated

from d-c. power lines. The filaments of these tubes supply heat to the electron-emitting cathode, as in the case of the heater-type a-c. tubes. Thus fluctuations in the source of power, such as is possible with the storage battery of an automobile, have relatively little effect on this filament and a constant stream of electrons is assured. No resistance is necessary in the filament circuit when these tubes are operated from a storage battery, but they are connected in series when the source of power is the d-c. power lines, then their filament current should be adjusted carefully to 0.3 ampere.

The Duplex-Diode Triode.¹—This is one of the most revolutionary tubes that has ever come out

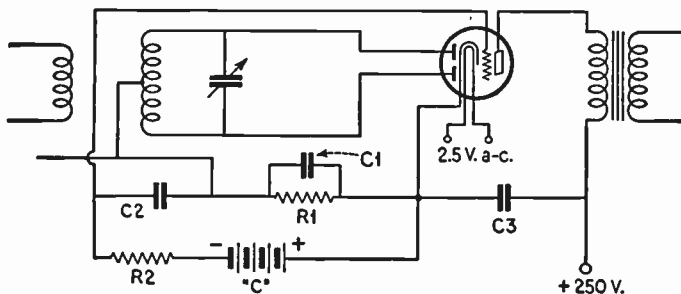


FIG. 82B.—The two diodes can be connected as shown to obtain full-wave rectification.

of a laboratory, as it really is three tubes in one glass envelope. The '55 type consists of two diodes and a triode, these being independent of each other except for the common cathode, which has one electron-

¹A "diode" is a vacuum tube having two elements, generally a filament and a plate. A "triode" is the same, with the addition of a third element, the grid, which is located between the other two.

emitting surface for the diodes and another for the triode.

It has been stated heretofore that the simplest form of a vacuum tube detector was a diode, which depends for its rectifying properties on the fact that current will flow only from the cathode (filament) to the plate, when the plate is positive with respect to the cathode. As the diode is a simple rectifier, it has no amplifying properties and if an increased current is desired then other tubes must be introduced into the circuit. This will be explained later.

The two diodes in the '55 tube can be used for

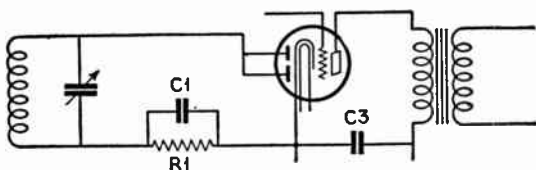


FIG. 82C.—The plates of the duplex-diode tube here are connected for half-wave rectification.

full-wave rectification, see *Fig. 82B*, or their plates may be connected in parallel for half-wave rectification, see *Fig. 82C*. The former has some advantages, one being that no carrier frequency gets through to the grid of the following tube, but the latter gives about twice the output, necessitating some carrier-frequency filtering.

For amplifying the rectified signal, the triode is employed in the usual circuit arrangement, see *Fig. 82B*. The necessary grid-bias voltage may be obtained from a fixed voltage tap on the d-c. power supply or the variable voltage drop caused by the rectified

current flowing through a resistor in the detector circuit can be utilized. The values of the various condensers and resistors in *Fig. 82B* are given here-with: C1 has a capacity of 150 mmf.; C2, 0.01 mf.; C3, .1 mf.-1.0 mf.; R1 and R2, approximately 0.5 megohm. The C battery, supplying the negative grid bias, should be -20 volts, and the plate voltage should be 250, with 2.5 volts a.c. on the heater element.

CHAPTER XX

AN EXPERIMENTAL CONTINUOUS-WAVE TELEGRAPH TRANSMITTER

IN the first part of this book we learned about spark-gap telegraph sets, and how the oscillations they set up are *damped*, and the waves they send out are *periodic*. In this and the next chapter we shall find out how vacuum tube telegraph transmitters are made, and how they set up oscillations that are *sustained*, and radiate waves that are *continuous*.

Radio telegraph messages sent by continuous waves are preferable to messages sent by periodic waves. The transmitter can be: (1) more sharply tuned, (2) it will send signals farther with the same amount of power, and (3) it is noiseless in operation. The disadvantageous features are that: (1) a battery current is not satisfactory, (2) its circuits are somewhat more complicated, and (3) the oscillator tubes burn out occasionally. There is, however, a growing tendency among amateurs to use continuous-wave transmitters, and they are certainly more up-to-date and interesting than spark-gap sets, which are to-day considered obsolete and not tolerated due to the interference they set up.

There are three practical ways by which continuous waves can be set up for sending either telegraphic signals or telephonic speech and music: (*a*) with an

oscillation arc lamp, (b) a *vacuum tube oscillator*, and (c) a *high-frequency alternator*. The oscillation arc was the earliest known way of setting up sustained oscillations, and it is now largely used for commercial high-power, long distance work. But since the vacuum tube has been developed to a high degree of efficiency and is the scheme that is now in vogue for amateur stations, we shall confine our efforts here to explaining the apparatus necessary and how to wire the various parts together to produce a vacuum tube telegraph transmitter. The high-frequency alternator is used only for high-power stations.

Sources of Current for Telegraph Transmitting Sets.—A vacuum-tube oscillator differs from a spark-gap transmitter in that you cannot get very practical results with a low-voltage battery current. For a purely experimental vacuum tube telegraph transmitter you can use enough *B* batteries to operate it, but the current strength of these drops so fast when they are in use, that they are not at all satisfactory for the work.

You can, however, use 110-volt direct current from a lighting circuit as your initial source of power to energize the plate of the vacuum-tube oscillator of your experimental transmitter. Where you have a 110-volt, *direct-current* lighting service in your home and you want a higher voltage for your plate, you will then have to use a motor-generator set and this costs money. If you have a 110-volt, *alternating-current* lighting service at hand your troubles are over so far as cost is concerned, for you can step it up to any voltage you want with a power transformer.

An Experimental, Continuous-Wave Telegraph Transmitter.—You will remember that in *Chapter XVIII* we learned how the heterodyne receiver works and that in the separate heterodyne receiving set the second vacuum tube is used solely to set up oscillations. Now while this extra tube is used as a generator of oscillations these are, of course, very weak and hence a detector tube cannot be used to generate oscillations that are useful for other purposes than heterodyne receptors and measurements.

There are several vacuum tube amplifier tubes made, that will stand a plate potential of 100 volts, and any one of these can be used as a generator of oscillations by energizing it with a 110-volt direct current from your lighting service. Or in a pinch you can use five standard *B* batteries to develop the plate voltage, but these will soon run down. But whatever you do, never use a current from a lighting circuit on a tube of any kind that has a rated plate potential of less than 100 volts.

By consulting the vacuum tube chart in the back of the book you can tell at a glance what vacuum tubes you can and cannot safely use.

The Apparatus You Need.—For this experimental continuous-wave telegraph transmitter get the following pieces of apparatus: (1) one set of *inductance coils with clips*; (2) one *.002 mfd. fixed condenser*; (3) three *.001 mfd. condensers*; (4) one *adjustable grid leak*; (5) one *hot-wire ammeter*; (6) one *buzzer*; (7) one *dry cell*; (8) one *telegraph key*; (9) one *vacuum tube amplifier*; (10) one *6-volt storage battery*; (11) one *rheostat*; (12) one *oscillation choke coil*; (13) one *panel*

cut-out with a single-throw, double-pole switch, and a pair of fuse sockets on it.

The Tuning and Antenna Coils.—You can either make this tuning coil or buy one. To make it get two disks of wood $\frac{3}{4}$ -inch thick and 5 inches in diameter and four strips of hard wood, or better, hard

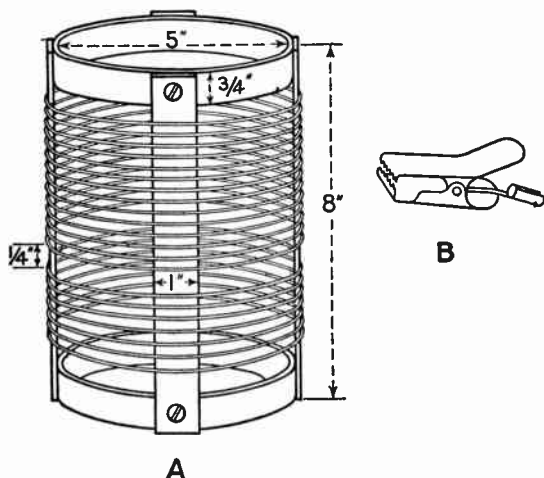


FIG. 83A.—Construction of tuning coil. B. Clip for tapping at the different turns.

rubber or bakelite strips, $\frac{1}{2}$ -inch thick, 1 inch wide and 8 inches long, and screw them to the disks as shown at A in *Fig. 83*. Now wrap on this form about 25 turns of No. 8 or 10, Brown and Sharpe gauge, bare copper wire with a space of $\frac{1}{8}$ -inch between each turn. About $\frac{1}{4}$ -inch from the lower end of this coil start the coil for the link circuit which consists of five turns. Get four of the smallest size terminal clips, see B, and clip them on to the different turns, when your tuning coil is ready for use.

A Continuous-Wave Telegraph Transmitter 225

The antenna coil is made the same size as the tuning coil except that it has but 20 turns of wire. The lead from the coil L2 is soldered to the center of

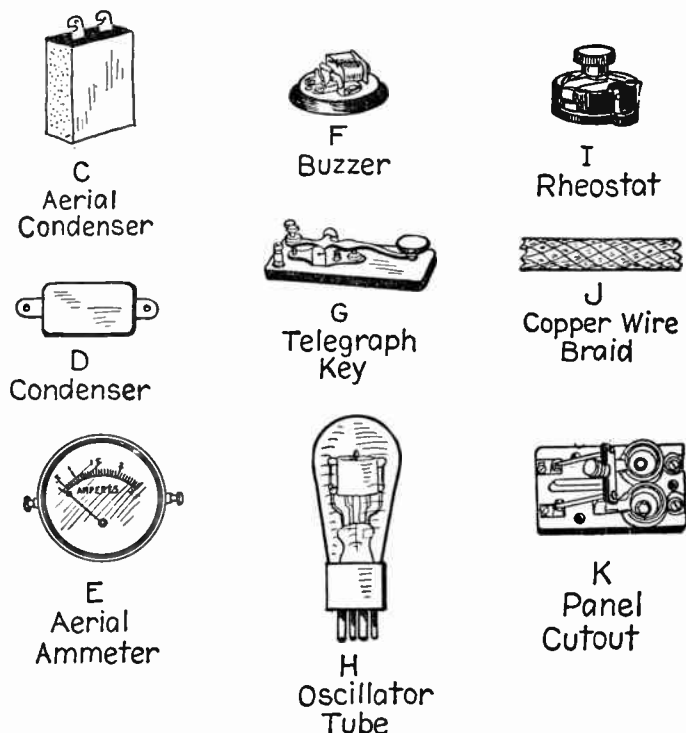


FIG. 84.—Some of the apparatus needed for a transmitter.

the coil and two clips are used for the other two connections.

The Condensers.—For the aerial series condenser get one that has a capacity of .002 mfd. and that will stand a potential of 3,000 volts. It is shown at *C*, Fig. 84. The other three condensers, see *D*, are

also of the fixed type and may have a capacity of .001 mfd.; the blocking condenser should preferably have a capacity of $\frac{1}{2}$ mfd. In these condensers the leaves of the sheet metal are embedded in composition.

The Aerial Ammeter.—This instrument is also called a *hot-wire* ammeter because the oscillating currents flowing through a piece of wire heat it according to their current strength and as the wire contracts and expands it moves a needle over a scale. The ammeter is connected in the aerial wire system, either in the aerial side or the ground side—the latter place is usually the most convenient. When you tune the transmitter so that the ammeter shows the largest amount of current surging in the aerial wire system you can consider that the oscillation circuits are in tune. A hot-wire ammeter reading to 1.5 amperes will serve your needs; it is shown at *E* in *Fig. 84*.

The Buzzer and Dry Cell.—While a heterodyne, or beat, receiver can receive continuous wave telegraph signals an ordinary crystal or vacuum tube detector receiving set cannot receive them unless they are broken up into trains either at the sending station or at the receiving station, and it is considered the better practice to do this at the former rather than at the latter station. For this small transmitter you can use an ordinary buzzer as shown at *F*. A dry cell or two must be used to energize the buzzer.

The Telegraph Key.—Any kind of a telegraph key will serve to break up the trains of sustained oscillations into dots and dashes. The key shown

at *G* is mounted on a composition base and is the cheapest key made.

The Vacuum Tube Oscillator.—As explained before, you can use any amplifying tube that is made for a plate potential of 100 volts or over. The current required for heating the filament is about 1 ampere at 6 volts. A bakelite socket should be used for this tube as it is the best insulating material for the purpose. An amplifier tube of this type is shown at *H*.

The Storage Battery.—A storage battery is used to heat the filament of the tube, just as it is with a detector tube, and it can be of any make or capacity as long as it will develop 6 volts. The cheapest 6-volt storage battery on the market has a 20 to 40 ampere-hour capacity.

The Battery Rheostat.—As with the receivers a rheostat is needed to regulate the current that heats the filament. A rheostat of this kind is shown at *I*.

The Oscillation Choke Coil.—This coil is connected in between the oscillation circuits and the source of current which feeds the oscillator tube to keep the oscillations set up by the latter from surging back into the service wires where they would break down the insulation. You can make an oscillation choke coil by winding say 100 turns of No. 28 Brown and Sharpe gauge double-cotton-covered magnet wire on a cardboard cylinder 2 inches in diameter and $2\frac{1}{2}$ inches long.

Transmitter Connectors.—For connecting up the different pieces of apparatus of the transmitter it is a good scheme to use *copper braid*; this is made of braided copper wire in three sizes.

The Panel Cut-Out.—This is used to connect the cord of the 110-volt lamp socket with the transmitter. It consists of a pair of *plug cut-outs* and a

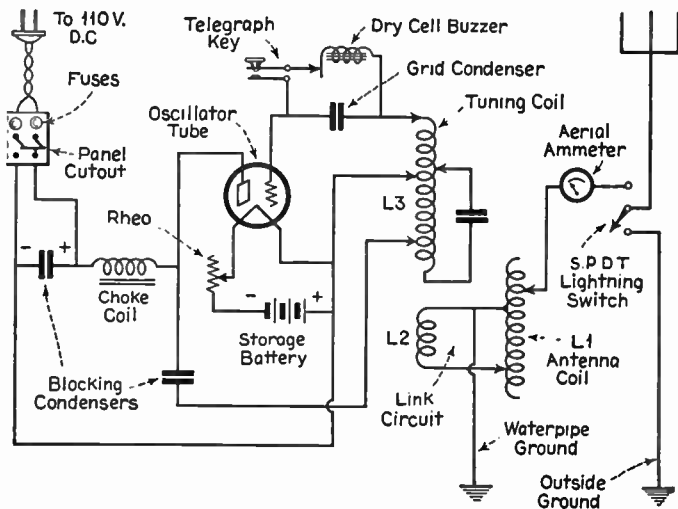


FIG. 85.—Diagram of experimental C.W. transmitter.

single-throw, double-pole switch mounted on a porcelain base as shown at *K*. In some localities it is necessary to place these in an iron box to conform to the requirements of the fire underwriters.

Connecting Up the Transmitting Apparatus.—The way the various pieces of apparatus are connected together is shown in the wiring diagram, *Fig. 85*.

CHAPTER XXI

AN EXPERIMENTAL TELEPHONE TRANSMITTER

In time past the most difficult of all electrical apparatus for the amateur to make, install and work was the radio telephone. This was because it required a *direct current* of not less than 500 volts to set up the sustained oscillations and all ordinary direct current for lighting purposes is usually generated at a potential of 110 volts.

Now as you know it is easy to *step-up* a 110-volt alternating current to any voltage you wish with a power transformer but until within comparatively recent years an alternating current could not be used for the production of sustained oscillations for the very good reason that the state of the art had not advanced that far. In the new order of things these difficulties have all but vanished, and while a radio telephone transmitter still requires a high-voltage direct current to operate it this is easily obtained from a 110-volt source of alternating current by means of *vacuum tube rectifiers*.

The pulsating direct currents are then passed through a filtering reactance coil, called a *reactor*, and one or more condensers, and these smooth them out until they approximate a continuous direct current. The latter is then made to flow through a

vacuum tube oscillator when it is converted into high-frequency oscillations and these are *varied*, or *modulated*, as it is called, by a *microphone transmitter* such as is used for ordinary wire telephony. The energy of these sustained modulated oscillations is then radiated into space from the aerial in the form of electric waves.

The distance that can be covered with a radio telephone transmitter is about one-fourth as great as that of a radio telegraph transmitter having the same input of initial current, but it is long enough to satisfy the most enthusiastic amateur. For instance with a radio telephone transmitter where an amplifier tube is used to set up the oscillations and which is made for a plate potential of 100 volts, distances of 5 or 10 miles can be covered.

With a single 5-watt oscillator tube energized by a direct current of 350 volts from either a motor-generator or from a power transformer (after it has been rectified and smoothed out) speech and music can be transmitted to upwards of 10 to 15 miles. Where two 5-watt tubes connected in parallel are used radio telephone messages can be transmitted to distances of 15 to 25 miles. Further, a single 50-watt oscillator tube will send to distances of 25 to 50 miles while two of these tubes in parallel will send from 50 to 100 miles. Finally, where four or five oscillator tubes are connected in parallel, proportionately greater distances can be covered.

A Short-Distance Radio Telephone Transmitting Set—With 110-Volt Direct Lighting Current.—For this very simple, short distance radio

telephone transmitting set you need the same apparatus as that described and pictured in the beginning of *Chapter XX for a Short-Distance C.W. Telegraph Transmitter*, except that you use a *microphone transmitter* instead of a *telegraph key*. If you have a 110-volt direct lighting current in your home you can

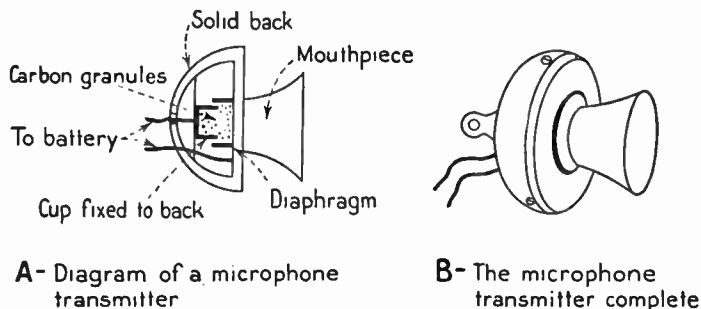


FIG. 86A and B.—A cross-sectional view and outward appearance of a microphone transmitter.

put up this short distance set for very little money and it will be well worth your while to do so.

The Apparatus You Need.—For this set you require: (1) one set of coils as described for the other transmitter as shown in *Fig. 84*; (2) one *aerial ammeter*; (3) one *aerial condenser*; (4) one *grid, blocking and protective condenser*; (5) one *grid leak*; (6) one *vacuum tube amplifier* which is used as an *oscillator*; (7) one *6-volt storage battery*; (8) one *rheostat*; (9) one *oscillation choke coil*; (10) one *panel cut-out* and an ordinary *microphone*.

The Microphone.—The best kind of a microphone to use with this and other telephone transmitting sets is a *Western Electric No. 284-W*. This

is known as a solid back transmitter and is the standard commercial type used on all long distance Bell telephone lines. It articulates sharply and distinctly and there are no current variations to distort the

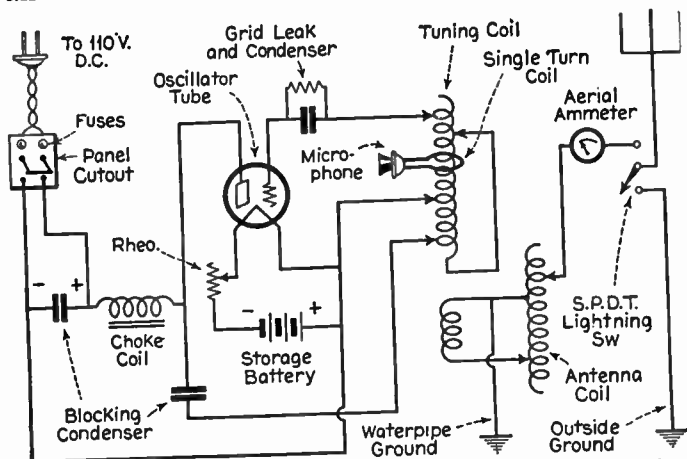


FIG. 87.—Diagram of phone transmitter, using the absorption modulation system.

wave form of the voice and it will not buzz or sizzle. It is shown in *Fig. 86*. Any other good microphone transmitter can be used if desired.

Connecting Up the Apparatus.—Connect the apparatus as shown in *Fig. 87*. The microphone terminals are connected to a *single turn* of wire that is inductively coupled to tuning coil, as indicated.

CHAPTER XXII

A LOW-POWER TELEGRAPH TRANSMITTER

BEFORE describing the transmitter the author wishes to bring to the attention of the reader once again that in order to operate a transmitting station, it is necessary to obtain a license to do so. Information as to how this may be obtained can be had from the Supervisor of the district in which you are a resident. (See *Radio Laws and Regulations* in the *Appendix*.)

The transmitters in this and the following chapters have been selected for their simplicity in assembly and operation, together with their relatively low cost and maintenance. They may be purchased either as a kit, which the operator can put together himself, or they may be had already assembled. If the amateur is "handy with his fists" and is a careful worker, it is recommended that he assemble his own transmitter, for in this way will he become thoroughly acquainted with the parts of his set and also save himself some money.

In *Fig. 88* will be found a circuit diagram of the transmitter. Referring to the diagram, this circuit is called a shuntfeed Hartley oscillator. Any type of vacuum tube having a UX-type base may be used, the power of the tube to a certain extent determining the range of the transmitter. With a UX-210 tube

this set should be heard a distance of 2000 miles, this of course, being dependent upon the location of the transmitter and the sensitivity of the receiver. This figure may be bettered, as similar transmitters have been reported to have worked stations 4000

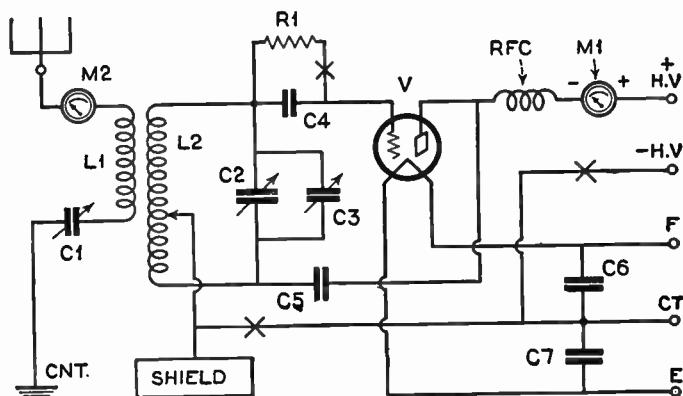


FIG. 88.—Schematic diagram of a low-power transmitter using a Hartley oscillator.

miles distant. The cost of the kit, exclusive of tubes and power supply, is approximately \$55.00.

The Functioning of the Circuit.—Considering the circuit diagram of *Fig. 89*, which is a Hartley oscillator, it will be seen that a coil, or inductance, *L*, is connected between the grid and the plate of the vacuum tube, *V*. At the midpoint of this coil, a tap is connected to the filament of the tube. Across the coil is shunted a variable condenser, which with the coil, is the oscillatory circuit.

If we impress an alternating voltage on the grid of *V* this voltage will be amplified in the plate circuit. If there is sufficient amplification to overcome the

loss of energy due to resistance in the circuit, the tube and the circuit shown will become a generator of r-f. oscillations. The alternating voltage to which we refer at the beginning of this paragraph is produced by the rise and fall of the plate current as it flows through the lower half of L, which is marked B.

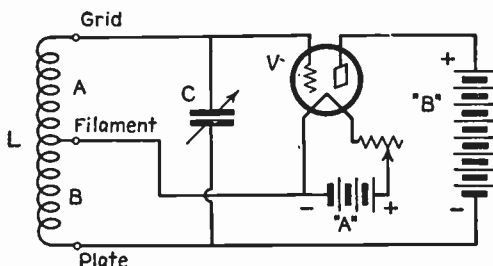


FIG. 89.—Fundamental Hartley oscillator circuit.

The flow of current in B is from the center tap down to the plate end of the coil, through the "B" battery and back to the plate of the tube. The current in the grid circuit, starting at the center tap goes up through the half of the coil marked A and returns to the grid of the tube.

As the operation of a vacuum tube oscillation generator has been explained elsewhere, it need merely to be stated that the oscillator circuit in this set is L2-C2. (See Fig. 88.) The frequency of this circuit (its wavelength) is controlled by the number of turns on L1-L2 and the setting of the tank condenser, C2-C3. The sustained oscillations generated in the circuit are interrupted by a telegraph key connected in any of the points marked X in the diagram.

If the key be operated, *i.e.*, the oscillating circuit

or its power supply be opened and closed, we will induce in L1 a series of oscillations of constant frequency if the circuit L1-C1 be in resonance with the oscillator. Like trains of oscillations are induced in the antenna circuit and they will be broadcast.

The antenna ammeter, M2, is of the thermocouple type and is so designed that it will indicate the amount of radio-frequency current flowing in the antenna circuit. When the condenser C1 is varied the reading of this meter will vary accordingly when within several degrees of the resonance point otherwise it will remain at 0, as by varying the condenser you are changing the frequency of the circuit. When circuits C1-L1 and C2-L2 are in resonance there will then occur the greatest transfer of current from the latter to the former, therefore the antenna ammeter may be used as an indicator for determining when the circuits are tuned to each other.

A milliammeter, M1, is inserted in the plate circuit of the tube, the full-scale reading being 100 d-c. milliamperes. This is used for reading the rectified current supplying the plate of the oscillator tube, which must be carefully watched when the set is being tuned.

Suggestions for Tuning the Transmitter.—The tuning of a transmitter will doubtless be found by the amateur to be rather a difficult task, yet after a bit of careful experimenting there should be no reason why he should not get the hang of it. In the tuning of a set certain precautions must be observed, otherwise the tube or some other piece of apparatus will be damaged.

A Low-Power Telegraph Transmitter 237

The tuning of a transmitter has two objects: (1) to get the highest efficiency from the oscillator; and (2) to obtain the maximum power output from the tube, or greatest antenna current at a given wavelength. The second of these two objects is generally considered by the amateur to be the more important, as he wishes to "get out" as far as possible with his set.

Before making any adjustments of the apparatus it is wise to reduce the plate voltage, so that there will be no danger of the tube overheating during experimentation. Check all connections again before closing the power supply switches.

Use a wavemeter for checking the frequency of the transmitter. (See *Chapter XXV* for construction and data on wavemeters.) The resonance point is indicated by the *highest* reading of the plate milliammeter. Ordinarily the coupling between the oscillator and antenna circuits has to be adjusted very carefully, but in the transmitters described in this and the following chapters, this adjustment has been made already by the manufacturer of the plug-in coils. In making adjustments for maximum power output take care that the plate current of the tube is not excessive and remember that maximum power in the tube does not mean maximum antenna current at every wavelength but *at one particular wavelength*. Strive for the highest antenna current at the wavelength for which your installation is designed.

The Parts Required and How to Connect Them.— You will need the following parts for assembling the REL 10-watt Transmitter:

- 1 set of plug-in inductances, L1-L2
 - 1 transmitter coil base
 - 1 210 mmf. variable condenser, C1
 - 1 100 mmf. tank condenser with vernier, C2-C3
 - 1 2000 mmf. grid-blocking condenser, C4
 - 1 2000 mmf. plate-blocking condenser, C5
 - 2 2000 mmf. bypass condensers, C6-C7
 - 1 5000 ohm transmitting grid leak, R1
 - 1 r-f. choke coil, RFC
 - 1 0-100 d-c. milliammeter, M1
 - 1 0-1 amp. thermocouple r-f. ammeter, M2
 - 1 UX-type tube socket
 - Necessary hardware, cabinet, panels, etc.
- See *Fig. 88* for diagram of connections.

CHAPTER XXIII

A COMBINATION 10-WATT TELEPHONE AND TELEGRAPH TRANSMITTER

BEFORE describing this transmitter the author again wishes to remind the reader that it is necessary to obtain a Government license to operate a radio transmitter. The Supervisor of the radio district in which you live will supply you with details as to how this license may be obtained and how to prepare for the examination, which must be passed in order to obtain it.

The combination telephone and telegraph transmitter described in this chapter is excellent from several viewpoints. It may be used for either straight C.W. transmission (code) or it may be used for voice transmission, the changeover being quite simple. Any type of tubes may be employed, as long as it has a UX-type base and the power supply may be either storage battery or alternating current. This transmitter will have a telephone range of approximately 5 to 500 miles and a telegraph range of from 50 to 2000 miles, depending on the tubes employed, the location of the set, etc. The price is reasonable, approximately \$70.00 exclusive of tubes, accessories, power supply, etc. It may be purchased in either assembled or knock-down form, the assembled set costing about \$25.00 more.

The circuit used is a combination of a single-tube Hartley oscillator and a single-tube Heising modulator. The Hartley oscillator circuit was the one described in the previous chapter and the system of modulation will be described below.

How the Transmitter Functions.—It will be remembered from the chapter dealing with vacuum

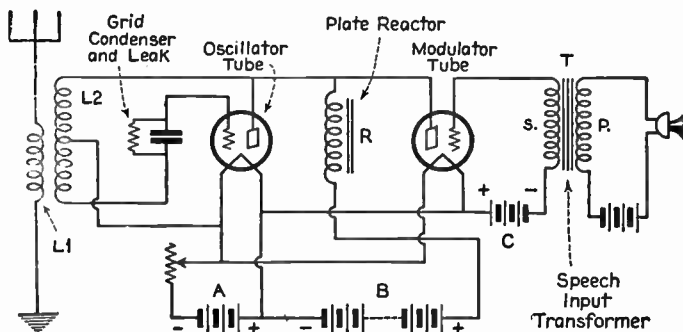


FIG. 90.—Simplified diagram of a Hartley oscillator and Heising modulator transmitter.

tubes that the plate current of a tube may be varied in two ways: by changing the plate voltage or by varying the voltage applied to the grid, when the plate potential is kept constant.

Now let us assume that we have an oscillator tube generating radio-frequency oscillations. See *Fig. 90*, which has been reduced to the mere essentials for clarity. This consists of an oscillator tube, the plate of which is directly connected to the plate of a second tube, called the *modulator*. Supplying plate voltage to both these tubes is a "B" battery, with a lead common to the two tubes. In the grid circuit

of the modulator tube is connected the secondary of a *speech-input* transformer.

In order to vary the plate current of the oscillator the two courses mentioned above are open—and we will choose the first one mentioned, *i.e.*, by varying the plate voltage. However, this voltage must be varied so that it will cause the oscillations generated in the tube to vary exactly the same as the voltage varies in the microphone circuit.

First of all it is necessary to have an absolutely steady supply of direct current to the plates of both tubes. A coil, R, of high impedance (an iron-core choke coil) is connected in the lead between the plates and the positive terminals of the “B” battery. The steadying action of this choke is based on the fact that a choke of this nature will tend to oppose any *current change* in its circuit.

Now if one of the tubes draws more current momentarily and as there is only so much current flowing in the circuit, this necessarily takes some of the available supply from the second tube. On the other hand, if the current taken by the first tube be reduced then the other tube gets more for the time being.

Now as the plate current can be varied by changing the grid voltage, we can effect this variation in the plate current of the modulator tube by placing in its grid circuit the secondary of an a-f. transformer. In the primary circuit of this *speech-input* transformer is connected a microphone with its energizing battery.

Let us now trace the operation from the microphone to the antenna. A sentence is spoken into the “mike”

and the varying frequencies cause a similar voltage to be induced in the secondary, S. This set of frequencies set up in the grid circuit of the modulator tube affect the plate current so that at different instants it draws now more, now less current from the steady supply delivered by the "B" battery. As this variation in plate voltage affects the plate current of the oscillator tube so the output of this tube delivered to the coil, L2, will be affected. In other words the audio-frequency oscillations set up in the grid circuit of the modulator tube cause the radio-frequency oscillations of the second tube to vary in their amplitude. These varying oscillations induce a similar set in L1, which cause the antenna circuit to oscillate in the same manner.

The action of the speech-input transformer might be confusing inasmuch as there is apparently no alternating current in the circuit, only a d-c. battery. However, it must be remembered that any noise or note is caused by the air vibrating at a certain frequency. For instance, the key, middle C, on a piano has a frequency of 256 cycles per second; a man's voice frequency range is from about 100 to 2000 cycles per second, etc.

Now when a certain note for example is sounded before a microphone the diaphragm vibrates at the same frequency as does the air. The vibrating diaphragm sets up in the primary circuit of the speech-input transformer a corresponding electrical frequency, which is really pulsating direct current by the definition given previously. The voltage changes of this current act upon the secondary of the trans-

A 10-Watt Telephone-Telegraph Transmitter 243

former as if it were alternating current, so that the output is really a-c.

In the circuit diagram of the complete combination transmitter shown in *Fig. 91*, it will be noted that a radio-frequency choke coil, RFC, is placed between

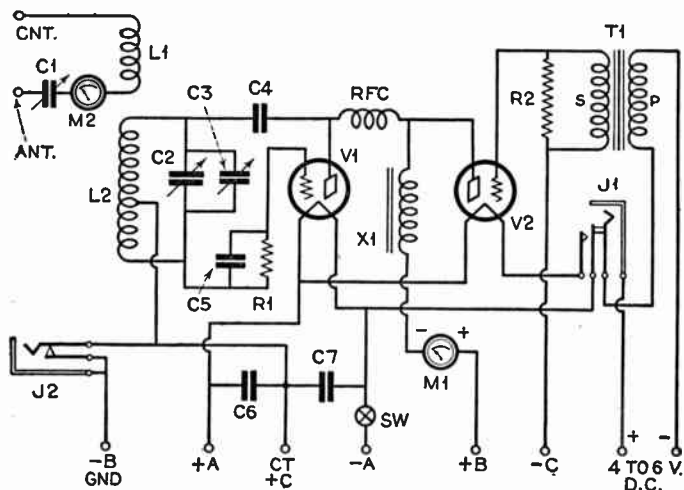


FIG. 91.—Complete diagram of the telephone or telegraph combination transmitter.

the plate of the oscillator tube and the junction of the leads from X1, the reactor, and the plate of the modulator tube, V2. This choke is for the purpose of preventing the high-frequency oscillations generated in V1 from getting into V2 and causing trouble.

If the circuit of the jack, J2, be traced out it will be seen that when a telegraph key is plugged in, it will be a part of the grid circuit of the oscillator tube, coming from the center tap of the power transformer,

CT, through the jack, through the lower half of L2, through the grid leak and thence to the grid.

The circuit of the jack, J1, is a bit more complicated, as this jack performs two operations. It will be noted that the two left-hand contacts are open in normal position. If the circuit of these be traced out you will find that the filament of the modulator tube will not be lit with the jack in the position shown. Also the 4-6 volt microphone-battery circuit is open, tracing this through the jack, the primary of T1 and back to the battery terminals. When a plug to which is connected a microphone is inserted in J1, both these circuits will be closed and it will be equivalent to the input circuit as is shown in *Fig. 89*.

This arrangement is made so that when the power switch is thrown connecting the filament power supply to the filament circuit, only the oscillator tube's filament will light, when the set is being used for C.W. transmission. When the plug is removed from J2 and the other inserted in J1, the filament of the modulator will light. The modulator is of course needed for telephony.

The meters, M1 and M2, are for the same use as those described in the previous chapter.

The Parts Required and How to Connect Them.— You will need the following parts for assembling this combination transmitter:

- 1 set of plug-in inductances, L1-L2
- 1 210 mmf. antenna series variable condenser, C1
- 1 tank condenser with 100 mmf. vernier condenser, C2-C3
- 1 plate blocking condenser, 2000 mmf., C4
- 1 grid condenser, 2000 mmf., C5

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- 2 bypass condensers, 2000 mmf., C6-C7
 - 1 0-200 d-c. milliammeter, M1
 - 1 0-1 thermocoupled r-f. ammeter, M2
 - 1 5000-ohm grid leak, R1
 - 1 100,000-ohm resistor, R2
 - 1 r-f. choke coil, RFC
 - 1 modulation transformer, T1
 - 1 filament switch, SW
 - 1 1½-heavy constant-current choke coil, X1
 - 1 microphone jack, J1
 - 1 Key jack, J2
 - 2 UX-type sockets
 - Cabinet, panels, connecting wire, hardware, etc.
- See *Fig. 91* for diagram of connections.

CHAPTER XXIV

THE OPERATION OF VACUUM TUBE TRANSMITTERS

The foregoing chapters explained in detail the design and construction of (1) two kinds of C.W. telegraph transmitters, and (2) two kinds of radio telephone transmitters, the difference between them being whether they used (A) a direct current, or (B) an alternating current as the initial source of energy. Of course there are other differences between those of like types as, for instance, the apparatus and connections used (a) in the key circuits, and (b) in the microphone circuits. But in all of the transmitters described of whatever type or kind the same fundamental device is used for setting up sustained oscillations and this is the *vacuum tube*.

The Operation of the Vacuum Tube Oscillator.—The operation of the vacuum tube in producing sustained oscillations depends on (1) the action of the tube as a valve in setting up the oscillations in the first place and (2) the action of the grid in amplifying the oscillations thus set up, both of which we explained previously. In *Chapter XVIII* it was pointed out that a very small change in the grid potential causes a corresponding and larger change in the amount of current flowing from the plate to the filament; and that if a vacuum tube is used for the

production of oscillations the initial source of current must have a high voltage; in fact the higher the plate voltage the more powerful will be the oscillations.

To understand how oscillations are set up by a vacuum tube when a direct current is applied to it, take a look at the simple circuit shown in *Fig. 92*. Now when you close the switch, the voltage from the battery charges the condenser and keeps it

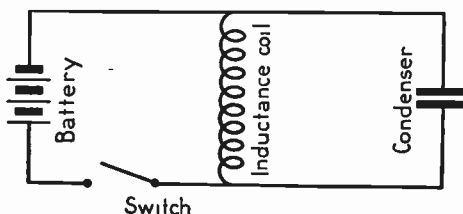


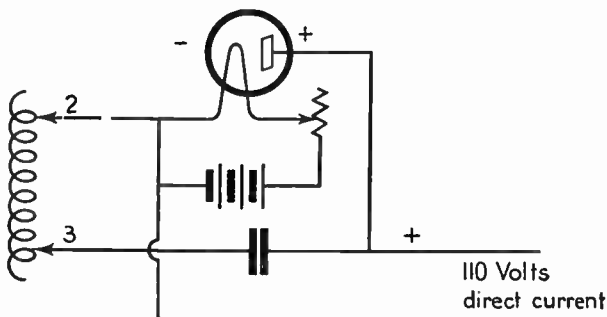
FIG. 92.—Diagram of connections showing how a direct current sets up oscillations.

charged until you open it again; the instant you do this the condenser discharges through the circuit which includes it and the inductance coil, and the discharge of a condenser is always oscillatory.

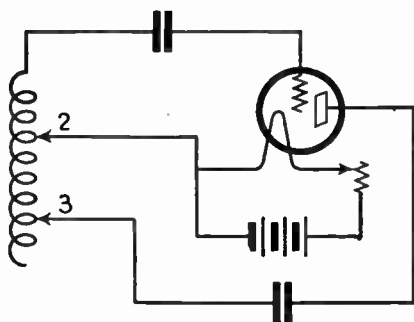
Where an oscillator tube is included in the circuits shown at *A* and *B* in *Fig. 93*, the grid takes the place of the switch and any slight change in the voltage of either the grid or the plate is sufficient to start a train of oscillations going. As these oscillations surge through the tube, the positive parts of them flow from the plate to the filament and these carry more of the direct current with them.

To make a tube set up powerful oscillations then, it is only necessary that an oscillation circuit shall be provided which will feed part of the oscillations

set up by the tube back to the grid circuit, and when this is done the oscillations will keep on being amplified until the tube reaches the limit of its output.



A-The high voltage direct current and plate oscillation circuits



B-The plate and grid oscillation circuits

FIG. 93. A and B.—Illustrating the operation of a vacuum-tube oscillator.

The Operation of C.W. Telegraph Transmitters With Direct Current—Short-Distance C.W. Transmitter.—In the transmitter shown in the wiring

diagram in *Fig. 85* the positive part of the 110-volt direct current is carried down from the lamp socket through one side of the panel cut-out, thence through the choke coil and to the plate of the oscillator tube, when the latter is charged to the positive sign. The negative part of the 110-volt direct current then flows down the other wire to the filament so that there is a difference of potential between the plate and the filament of 110 volts. Now when the 6-volt battery current is switched on the filament is heated to brilliancy, and the electrons thrown off by it form a conducting path between it and the plate; the 110-volt current then flows from the latter to the former.

Now follow the wiring from the plate over to the blocking condenser, to the tuning coil, through the turns of the latter to the filament and, when the latter is heated, you have a *closed oscillation circuit*. The oscillations surging in the latter set up other and like oscillations in the tuning coil, and these surge through the circuit formed by this portion of the coil, the grid condenser and the filament; this is the amplifying circuit and it corresponds to the regenerative circuit of a receiving set.

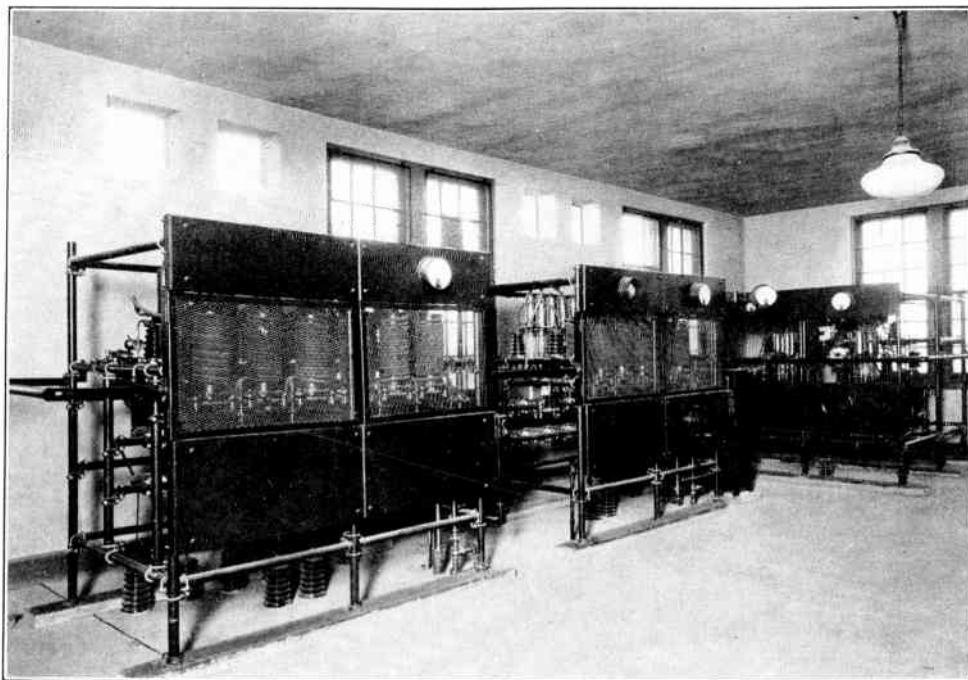
When oscillations are set up in it the grid is alternately charged to the positive and negative signs. These reversals of voltage set up stronger and ever stronger oscillations in the plate circuit as before explained. Not only do the oscillations surge in the closed circuits, but they run to and fro on the aerial wire after going through the link circuit, when their energy is radiated in the form of electric waves. The oscillations are varied by means of the telegraph

key which is placed in the grid circuit as shown in *Fig. 85*.

The Operation of the Key Circuit.—The effect in a C.W. transmitter when a telegraph key is connected in series with a buzzer and a battery and these are shunted around the condenser in the grid circuit, is to change the wave form of the sustained oscillations rapidly. While no sound can be heard in the headphones at the receiving station so long as the points of the key are not in contact, when they are in contact the oscillations are modulated and sounds are heard in the headphones that correspond to the frequency of the buzzer in the key circuit.

The Operation of C.W. Telegraph Transmitters with Direct Current.—The chief differences between the long-distance sets which use a direct current, and the short-distance transmitting sets are that the former use: (1) a motor-generator set for changing the low-voltage direct current into high-voltage direct current, and (2) a chopper in the key circuit.

The chopper interrupts the oscillations surging through the grid circuit at a frequency that the ear can hear, that is to say, about 800 to 1,000 times per second. When the key is open, of course, the sustained oscillations set up in the circuits will send out continuous waves but when the key is closed these oscillations are broken up and then they send out discontinuous waves. If a heterodyne receiving set, see *Chapter XVIII*, is being used at the other end you can dispense with the chopper and the key circuit needed is very much simplified. The operation of key circuits of the latter kind will be described presently.



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The transmitter at WJZ, Bound Brook, N. J.

The Operation of C.W. Telegraph Transmitters with Alternating Current—With a Single Oscillator Tube.—Where an oscillator tube telegraph transmitter is operated by a 110-volt alternating current as the initial source of energy, a buzzer, chopper or other interruptor is not needed in the key circuit. This is because oscillations are set up only when the

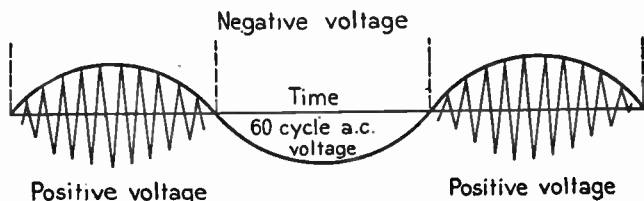


FIG. 94.—Positive voltage only sets up oscillations.

plate is energized with the positive part of the alternating current, and this produces an intermittent musical tone in the headphones. Hence this kind of a sending set is called a *tone transmitter*.

Since oscillations are set up only by the positive part or voltage of an alternating current it is clear that, as a matter of fact, this kind of a transmitter does not send out continuous waves and therefore it is not a C.W. transmitter. This is graphically shown by the curve of the wave form of the alternating current and the oscillations that are set up by the positive part of it in *Fig. 94*. Whenever the positive half of the alternating current energizes the plate then oscillations are set up by the tube and, conversely, when the negative half of the current charges the plate no oscillations are produced.

You will also observe that the oscillations set up

by the positive part of the current are not of constant amplitude, but start at zero the instant the positive part begins to energize the plate, and they keep on increasing in amplitude as the current rises in voltage until the latter reaches its maximum; then as it gradually drops again to zero the oscillations decrease proportionately in amplitude with it.

Heating the Filament with Alternating Current.—Where an alternating current power transformer is used to develop the necessary plate voltage, a second secondary coil is generally provided for heating the filament of the oscillation tube. This is better than a direct current for it adds to the life of the filament. When you use an alternating current to heat the filament keep it at the same voltage rather than at the same amperage (current strength). To do this you need only to use a voltmeter across the filament terminals instead of an ammeter in series with it; then regulate the voltage of the filament with a rheostat.

The Operation of C.W. Telegraph Transmitters with Alternating Current—With Two Oscillator Tubes.—By using two oscillator tubes and connecting them up with the power transformer and oscillating circuits the plates are positively energized alternately with every reversal of the current and, consequently, there is no time period between the ending of the oscillations set up by one tube and the beginning of the oscillations set up by the other tube. In other words, these oscillations are sustained but as in the case of those of a single tube, their amplitude rises and falls. This kind of a set is called a *full-wave rectification* transmitter.

The waves radiated by this transmitter can be received by either a crystal detector or a plain vacuum tube detector but the heterodyne receiver will give you better results than either of the foregoing types.

The Operation of Radio Telephone Transmitters with Direct Current—Short-Distance Transmitter.—The operation of this short-distance radio telephone transmitter, a wiring diagram of which is shown in *Fig. 85* is exactly the same as that of the *Direct Current Short-Distance C.W. Telegraph Transmitter* already explained in this chapter. The only difference in the operation of these sets is the substitution of the *microphone transmitter* for the telegraph key.

The Microphone Transmitter.—The microphone transmitter that is used to vary, or modulate, the sustained oscillations set up by the oscillator tube and circuits is shown in *Fig. 86*. By referring to the diagram at *A* in this figure you will readily understand how it operates. When you speak into the mouthpiece the *sound waves*, which are waves in the air, impinge upon the diaphragm and these set it into vibration—that is, they make it move to and fro.

When the diaphragm moves towards the back of the transmitter it forces the carbon granules that are in the cup closer together; this lowers their resistance and allows more current from the battery to flow through them. When the pressure of the air waves is removed from the diaphragm it springs back towards the mouthpiece, and the carbon gran-

ules loosen up when the resistance offered by them is increased and less current can flow through them. Where the oscillation current in the aerial wire is small the transmitter can be connected directly in series with the latter when the former will surge through it. As you speak into the microphone transmitter, its resistance is varied and the current strength of the oscillations is varied accordingly.

The Operation of Radio Telephone Transmitters with Direct Current—Long-Distance Transmitters.—In the radio telephone transmitters for long-distance work a battery is used to energize the microphone transmitter, and these two elements are connected in series with a *microphone modulator*. This latter device may be either: (1) a *telephone induction coil*, (2) a *microphone transformer* or (3) a *magnetic modulator*. The first two of these devices step-up the voltage of the battery current, and the amplified voltage thus developed is impressed on the oscillations that surge through the closed oscillation circuit or the aerial wire system according to the place where you connect it. The third device works on a different principle and this will be described a little farther along.

The Operation of Microphone Modulators—The Induction Coil.—This device is really a miniature transformer, and its purpose is to change the 6-volt direct current that flows through the microphone into 100-volts alternating current; in turn, this is impressed on the oscillations that are surging in either (1) the grid circuit, (2) the aerial wire system. When the current from the battery flows through

the primary coil it magnetizes the soft iron core and as the microphone varies the strength of the current the high-voltage alternating currents set up in the secondary coil of the induction coil are likewise varied, when they are impressed upon and modulate the oscillating currents.

The Microphone Transformer.—This is an induction coil that is designed especially for radio telephone modulation. The iron core of this transformer is also of the open magnetic circuit type, and the *ratio* of the turns of the primary and the secondary coil is such that when the secondary current is impressed upon either the grid circuit or the aerial wire system it controls the oscillations flowing through it with the greatest efficiency.

The Magnetic Modulator.—This piece of apparatus is also called a *magnetic amplifier*. The iron core is formed of very thin plates, or *laminations* as they are called, and this permits high-frequency oscillations to surge in a coil wound on it. In this transformer, the current flowing through the microphone varies the magnetic permeability of the soft iron core by the magnetic saturation of the latter. Since the microphone current is absolutely distinct from the oscillating currents surging through the coil of the transformer a very small direct current flowing through a coil on the latter will vary or modulate very large oscillating currents surging through the former.

Operation of the Vacuum Tube as a Modulator.—Where a microphone modulator of the induction coil or microphone transformer type is connected in the

grid circuit, the modulation is not very effective, but by using a second tube as a *modulator*, as shown in *Fig. 91*, an efficient degree of modulation can be had. Now there are two methods by which a vacuum tube can be used as a modulator: (1) by the *absorption* of the energy of the current set up by the oscillator tube; and (2) by *varying* the direct current that energizes the plate of the oscillator tube.

The first of these two methods is not often used because it absorbs the energy of the oscillating current produced by the tube and it is therefore wasteful. The second method is an efficient one, as the direct current is varied before it passes into the oscillator tube. This is sufficient reason for describing only the second method. The voltage of the grid of the modulator tube is varied by the secondary coil of the induction coil or microphone transformer, above described. In this way the modulator tube acts like a variable resistance but it amplifies the variations impressed on the oscillations set up by the oscillator tube.

The Operation of Radio Telephone Transmitters with Alternating Current.—Where an initial alternating current is used for radio telephony, the current must be rectified first by a pair of rectifier vacuum tubes and then smoothed out before passing into the oscillator tube to be converted into oscillations. In this case there will be no break in the continuity of the oscillations set up and therefore in the waves that are sent out.

The Operation of Rectifier Vacuum Tubes.—The vacuum tube rectifier is simply a two electrode vac-

uum tube. The way in which it changes a commercial alternating current into pulsating direct current is the same as that in which a two electrode vacuum tube detector changes an oscillating current into pulsating direct currents, and this has been explained in detail under the heading of "The Operation of a Two Electrode Vacuum Tube Detector" in *Chapter VII*. In the "A Low-Power Telegraph Transmitter" described in *Chapter XXII*, the oscillator tubes act as rectifiers as well as oscillators but for radio telephony the alternating current must be rectified first so that a continuous direct current will result.

The Operation of Reactors and Condensers.—A reactor is a single coil of wire wound on an iron core, and it should preferably have a large inductance. The reactor for the plate and grid circuit of a radio telephone transmitter where one or more tubes are used as modulators as shown in the wiring diagram in *Fig. 90*, and the filter reactor operate in the same way.

When an alternating current flows through a coil of wire the reversals of the current set up a *counter electromotive force* in it which opposes, that is *reacts*, on the current, and the *higher* the frequency of the current the *greater* will be the *reactance*. When the positive half of an alternating current is made to flow through a large resistance, the current is smoothed out, but at the same time a large amount of its energy is used up in producing heat.

But when the positive half of an alternating current is made to flow through a large inductance it acts like a large resistance as before and likewise smooths

out the current, but none of its energy is wasted in heat and so a coil having a large inductance, which is called an *inductive reactance*, or just *reactor* for short, is used to smooth out, or filter, the alternating current after it has been changed into a pulsating direct current by the rectifier tubes.

A condenser also has a reactance effect on an alternating current but different from an induction coil the *lower* the frequency the *greater* will be the reactance. For this reason both a filter reactor and *filter condensers* are used to smooth out the pulsating direct currents.

CHAPTER XXV

THE CONSTRUCTION AND USE OF WAVEMETERS

If you were to ask an old-timer in the transmitting game what was his favorite piece of apparatus and one without which he would be lost, the chances are that the answer would be his wavemeter. This instrument, cheap and easy of construction, is one of the handiest things on the amateur's list.

With it the transmitter can be tuned and checked; nodes on the antenna and counterpoise can be located; oscillators may be calibrated, as well as receivers; it may be used as a wavetrapp; and capacities or inductances can be measured. It is one of the simplest pieces of apparatus that the amateur can build and it is recommended that one be added to the "ham's shack" as soon as possible.

The essential parts of a wavemeter are but three: a variable condenser; a coil and an indicating device. The condenser should be of high-quality workmanship, enclosed in a metal case if possible, thus eliminating hand capacity effects. The value of its capacity should be 0.0005 mf. The coil may be wound by the amateur. The indicating device for determining the point of resonance may be a neon lamp or a plate milliammeter or voltmeter, the neon lamp being, of course, the cheapest and sufficiently accurate for ordinary use.

Let us consider some of the uses to which a wavemeter may be put and the manner in which it operates. First, let us see how frequencies are determined. If there is applied to a circuit a relatively small electromotive force it is possible to induce in this circuit a fairly large current, provided that the latter circuit be *in tune*, or in *resonance*, with the circuit in which the e.m.f. is flowing. Now a wavemeter is used to ascertain when the point of resonance is reached at some particular frequency or to find the frequency at which a circuit is in resonance. This is the same thing, it will be remembered, that occurs when you receive a station on your receiver—you “tune-in” the broadcast station’s signals till you get them with maximum volume and clarity. This means that your receiver circuit is in resonance with the transmitter’s circuit.

This phenomenon of resonance is the principle underlying wavemeters. The variable condenser of the wavemeter is varied until the neon lamp glows at maximum intensity or if a meter is used, until the needle shows a maximum reading.

The most important thing about a wavemeter is that it must be calibrated accurately or it will not serve its purpose. That is, you must know exactly at what frequency the wavemeter circuit is in resonance for every reading of the condenser with a particular coil. This may be done in several ways. After the wavemeter is built according to the specifications given below you can take it to someone who has a wavemeter and by using his transmitter operating at certain frequencies, your instrument can be calibrated.

Several broadcast stations also transmit at regular periods each month standard frequencies. These you can pick up on your receiver and then calibrate your meter.

Another method that is a bit more trouble but sufficiently accurate for the amateur is given herewith. To calibrate anything at all, it is necessary to start out with something that is known to be exact. In this case it is a coil. We know that a coil of No. 26 D. C. C. wire (55 turns) wound on a form $2\frac{1}{2}$ -inches in diameter will resonate at 34.25 meters. The coil should be $2\frac{1}{8}$ inches long when the 55 turns are wound on.

Now we must get our receiving set oscillating at the same frequency as the coil. This may be done by holding the coil suspended from a strong or insulating rod near the coils of the receiver. Vary the condenser of the receiver until a "click" is heard in the phones. Hold the standard coil at such a distance from the set's coils that only a single click is heard. We now know that the set is oscillating at a wavelength of 34.25 meters or a frequency of 8753 kilocycles. The wavemeter is now brought near the oscillating receiver and the condenser varied until the indicating device shows it to be in resonance. This reading of the condenser scale is recorded.

It is necessary to get at least three readings of the condenser in order that we may draw a curve on a sheet of graph paper, so that any point of the scale for this particular coil can be known. The receiver's condenser is slowly turned to the higher wavelengths and once more the click will be heard. This will

occur at double the frequency of the first point, or 68.50 meters. This reading is also translated to the wavemeter's condenser reading. The same procedure is followed again, this time going down the scale from 34.25 meters until the click is again heard. This point will be at a wavelength of 17.125 meters.

With these three points a curve may be drawn on regular graph or cross-section paper by means of an "irregular curve," such as is used for drawing curves of varying diameter. Or if the amateur wishes to be more accurate, he may draw the calibration curve on logarithmic paper, in which case it will be a straight line.

Just as in the case of the short-wave receiver, if we wish to cover a number of different wavelength bands we must have a coil for each. These coils are extremely simple to wind. They are wound with No. 12 D. C. C. wire in a $3\frac{1}{2}$ -inch loop with no coil form, as the wire is stiff enough to be self-supporting. The turns of the wire may be fastened together by means of heavy thread. Two turns of wire are needed for a coil covering the 20-meter band; 4 turns for the 40-meter band, and 8 turns for the 80. These coils are connected to the two terminals of the variable condenser of the wavemeter.

If the wavemeter condenser is enclosed in a metal case the neon indicating lamp may be installed within the case very readily. It is connected as the coil, across the terminals of the condenser. A small hole— $\frac{1}{8}$ inch in diameter—may be drilled in the top of the metal case and the neon lamp viewed through it. This method is recommended as the glow lamp is in

darkness and the maximum intensity can be more readily recognized.

In case the constructor wishes to build other coils of standard inductance, this can be easily done. It will be noticed that $1\frac{1}{2}$ turns on the $2\frac{1}{2}$ -inch coil mentioned previously was approximately equal to 1 meter. Therefore, if you desire a 40-meter standard coil you will need in the neighborhood of 60 turns. The inductance of this coil can be checked exactly by listening-in to the standard-frequency transmissions from one of the broadcast stations. When the standard frequency has been received bring the coil near the receiver's coil as was described heretofore. Remove fractional turns of the wire until the click is heard. The coil will then have a natural wavelength of 40 meters. This can be done with any size coil.

Calibrating a Transmitter.—Attach the coil to the wavemeter that will cover the waveband in which you wish to transmit. From your calibration curve find the exact setting for the wavemeter condenser and set it at this reading. Now bring the wavemeter near enough to the closed circuit of the transmitter so that the neon lamp just glows when the two circuits are in resonance. The condenser of the transmitter is varied until maximum glow occurs in the neon lamp.

Calibrating a Receiver.—As the majority of the receivers for short waves employ an oscillating detector, you can calibrate your receiver so that you will know upon what wave you are listening. This is done in the same manner as you calibrated the wavemeter's standard coil. Set the wavemeter to a

certain reading and bring it near the coil of the receiver. When a click is heard then the two circuits will be in resonance. Sometimes it is wise to have the wavemeter at such a distance that two clicks will be heard very close together. Dial readings are taken of each click and the point of resonance will be half-way between them.

Measuring Capacity or Inductance.—It has been stated previously that a wavemeter may be used for the measurement of a capacity or inductance. If you have an oscillating circuit in which there is a known capacity then it is possible to determine the inductance of the circuit. The same is true if the inductance of a coil is known, the capacity being then easily determined. This is based on the formula:

$$\text{Wavelength } (\lambda) = 59,600 \times \sqrt{LC}$$

If the wavelength is known of a certain circuit and one or the other of the other two variables, L or C, then the other can be found by the following formulae:

$$C = \frac{\lambda^2}{3.56 \times 10^9 \times L} \qquad L = \frac{\lambda^2}{3.56 \times 10^9 \times C}$$

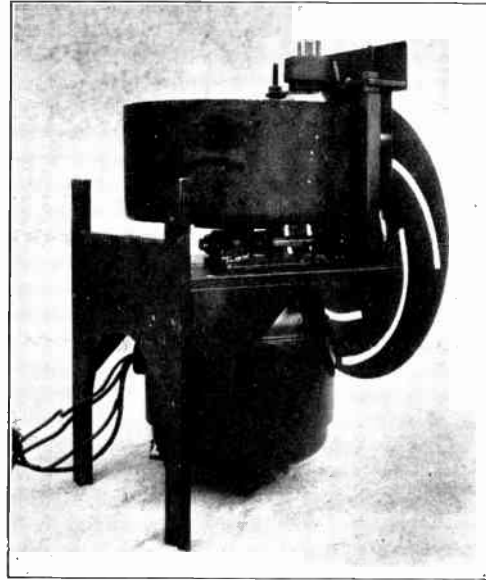
In these formulae, L is the inductance in millihenries, C, the capacity in microfarads and λ is the wavelengths in meters.

It might also be mentioned that a number of companies manufacture wavemeters having the same characteristics that have been described in this chapter. The cost is between \$15.00 and \$22.00. These meters are obtainable already accurately calibrated.



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The Jenkins Television or radiovision receiver. The images on the plate of the neon tube are enlarged by the lens in the front of the cabinet.



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The mechanism of the Jenkins Television, showing the scanning drum at the top, containing the vertically-mounted neon tube; the selector shutter at the right; and the synchronous motor for keeping a constant driving speed in step with the transmitter's scanning apparatus.

CHAPTER XXVI

RADIOVISION—THE AMATEUR'S NEXT JOB

It has been freely conceded that a vast amount of the progress that radio has made in the past twenty years has been due to the never-ending work and experimentation of the amateur. Men who are to-day leaders in the industry in many cases started experimenting with crystals and slide tuners in their attics just a little over a decade ago. They have made broadcasting what it is at the present time.

Now the amateur has another and just as interesting a problem before him to-day,—the transmission and reception of moving scenes by radio. Men who are now doing research along these lines are only too glad to have amateurs work with them, for they realize the earnestness and zeal that the younger generation put into such work. It is for this reason that this chapter has been included.

The subject of television or radiovision cannot be mentioned without the name of C. Francis Jenkins coming into the limelight. Perhaps no other man in this country has done more for moving pictures—and radiovision, it must be remembered, is a form of this type of entertainment—than this inventor. The apparatus described herewith is a product of his laboratories and if the amateur builds this apparatus, the signals which he will see will more than likely be broadcast from a Jenkins station.

In *Chapter XXVII* two distinct types of transmission and reception of living images are mentioned: those of the laboratory and those adaptable to the home. Apparatus such as has been developed by the Bell Telephone Laboratories is in a class by itself inasmuch as the cost ran well into the thousands of dollars. It is with the home reception of signals that we are concerned.

Television for the Amateur.—The apparatus for the reception of radiovision signals is not as complicated as might be expected. First of all is needed a short-wave radio receiver, such as is described in *Chapter X*, as the signals in most cases are broadcast in waves in the neighborhood of 140 meters. In *Fig. 51* will be found a circuit diagram of a receiver that is especially adapted for this purpose. It will be noticed that resistance-coupled audio-frequency amplification should be employed. Although this necessitates the use of an extra tube, this method of amplification has a wider frequency range than transformer coupling.

The radiovision apparatus itself consists of a scanning disk, a synchronous motor with which to drive it, a speed-regulating device of some sort, and a neon tube. The scanning disk has 48 holes and is generally about a foot in diameter. The holes are drilled in a spiral near the edge of the disk and are $1/32$ of an inch in diameter.

The motor, being of the synchronous type, will run at a constant speed when connected to a 110-volt, 60-cycle a-c. line. Its power need only be $1/20$ H.P. However, as the driving motor at the receiver



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Apparatus for recording sound on film for talking motion pictures. The film is in the reels on the table, the panel contains the mixing apparatus, the volume control and the control apparatus. In the carrying case is the microphone amplifier.

must run at exactly the same speed as the one at the transmitter, some sort of a speed regulating device must be employed.

The neon tube consists of two plates placed parallel and close together in a tube, which, after being evacuated, has been filled with neon gas. There are several types of these tubes on the market to-day and they are relatively inexpensive. It might also interest the reader to know that complete kits for building a receiver of this general type are obtainable at a reasonable cost.

The Operation of a Receiver.—There is nothing very mysterious about the operation of a receiver. If you will take a coin, place it beneath a sheet of thin paper, and draw with a soft pencil parallel lines close together over the whole area of the coin, you will find that you have reproduced the eagle or the figure of Liberty. The explanation is, of course, that the humps on the coin varied the pressure of the pencil on the paper to build up a picture, although the lines were drawn straight.

This is the same process that is used in building up images in the reception of radiovision or television. However, a pencil of light is used instead of the ordinary kind. This pencil of light sweeps across the object in successive parallel journeys and at a high speed. Photoelectric cells are affected by the reflected light from the object and their output is connected to the modulating circuit of a transmitter. In other words, the various intensities of light reflected from the object are equivalent to the varying pressure mentioned in connection with the humps in the coin.

These variations in current are broadcast on a carrier wave, just as the voice currents are in the more common form of broadcasting. When a radio receiver is tuned to that particular wave the result heard in a loud speaker is a series of high-pitched notes. When a radiovision receiver is switched on, however, then it is possible by carefully adjusting the motor's speed to *see* what is on the air.

It has been said that within the neon tube are two plates, these being about $1\frac{1}{2}$ by 2 inches in area. When the proper voltage is applied to the terminals of the tube these plates will glow with a brick-red color. When the output of the a-f. amplifier is connected to the tube, this will cause the light to vary in intensity at the same speed as the light reflections are picked up by the photoelectric cells at the broadcast station. The scanning disk is used at the receiver, so that our eyes only see a narrow band of the neon tube's plate at once, although due to the way the eye functions it *seems* as though we see the entire plate through the series of holes in the scanning disk.

Now in order to give to the eye the illusion that the image at which it is looking is in motion, there must be employed the same process which is used in the projecting of motion pictures on a screen. We must place before the eye fifteen complete pictures a second and then, just as in a movie theater, the eye will send to the brain a message that it sees an image that is in motion.

The size of the image is of course controlled by the size scanning disk and the area of the neon tube plate. It is an easy matter to enlarge the image by using a

lens, so that more than one person can enjoy the received signals.

The Jenkins Televisor.—For the first time in this country the laboratories of C. Francis Jenkins, under his direction, have developed an instrument for the reception of radiovision signals that may be said to be the equivalent of a manufactured radio receiving set. In other words, it will be soon possible to obtain a Televisor that is almost as simple to operate as the set through which you hear the music broadcast by the transmitting stations all over the country.

In principle this televisor is essentially the same as the apparatus just described, although some of the parts are changed a trifle for mechanical reasons. For instance, instead of the large scanning disk, a scanning drum is used. (See Plate.) The complete televisor is housed in a cabinet 18 by 18 by 24 inches. The front end of the cabinet contains a recessed opening or shadow-box, leading to a magnifying lens through which the image is viewed. Just under this opening is a small plate bearing the two switches that constitute the only controls necessary for operating the receiver.

The synchronous motor and the scanning drum are mounted vertically on a chassis and the neon tube is mounted in the center of the drum, which revolves around it. A small disk containing a number of parabolic slots, revolves between the drum and the lens of the receiver, providing a sharp cutoff of light, when necessary.

The image as seen through the lens is about six

inches square, which is large enough to be viewed with ease by five or six people. The operation of the receiver is quite simple and as may be seen from the illustrations the instrument itself is rugged so that it should be a source of entertainment as well as inspiration to those who are experimenting in this field.

Cathode-Ray Television.—Before this system of television can be explained it will be necessary to tell just what cathode rays are and how they are generated.

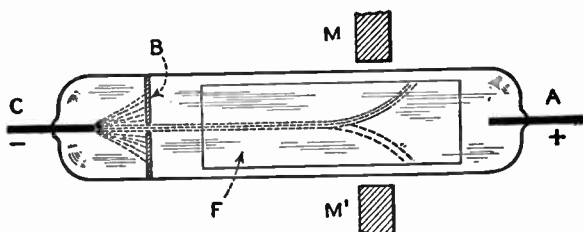


FIG. 95.—By means of the magnets, M and M', the stream of electrons can be deflected either up or down.

In the early days of this century experimenters found that if a high potential was placed across the terminals of a glass tube from which the air could be withdrawn, that a current flow could be maintained. By careful experimentation it was found that a stream of negative electrical charges traveled from the terminal connected to the negative side of the battery (or induction coil) over to the other terminal or electrode, as it is more commonly called. These negative charges were electrons and it was found also that they were capable of doing a number of things, some of which have been explained in previous chapters.

It was found that if a stream of electrons coming from the cathode, as the negative terminal is called, were concentrated in a thin ray, this ray could be deflected about the interior of the tube by means of a magnet held on the outside of the tube, as is shown in *Fig. 95*. *C*, the cathode, is the starting point of the electronic stream through the partially evacuated glass tube. *B* is a partition in the tube which stops all the electrons except those that can go through a small hole in the center. *A* is the anode or positive electrode. If a magnet is held at *M* the electronic stream can be seen to be deflected upwards, when a piece of fluorescent material, *F*, is placed in the path. If the magnet be moved to *M'* the stream will be deflected in the other direction, if the same pole of the magnet be held towards the tube. However, if the magnet's poles be reversed, then the stream will be deflected in the opposite direction.

From what you have read before, you know that when a current travels through the windings of a coil, a magnetic field is set up at the ends of the coil and this field has the same effect as that set up by a permanent magnet. Therefore, if two coils be substituted for the magnets at *M* and *M'* in *Fig. 95*, by passing a current through them at certain times, it would be possible to deflect the electronic stream as desired. Furthermore, if the end of the tube were to be enlarged and coated with a substance that would be fluorescent when struck by electrons and this used instead of the material at *F* in *Fig. 95*, then we would see a small spot of light on the end of the

tube that could be made to move from side to side according to the way current was sent through the coils at *M* and *M'*. See *Fig. 96*.

In this sketch the coils have been replaced by plates on which are impressed voltages of different polarities and these act upon the electronic stream in the same manner as did the magnets or coils.

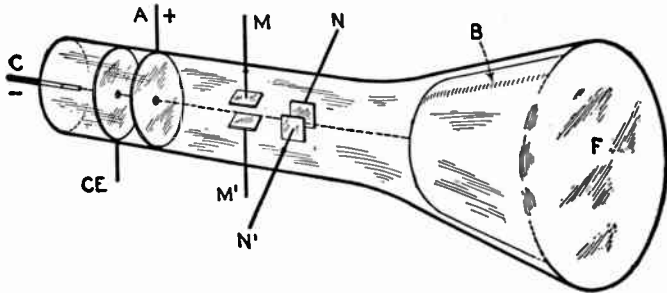


FIG. 96.—By means of the two sets of plates, *M-M'* and *N-N'*, the electronic stream from the cathode *C* can be deflected so that its appearance as a spot on *F* will move in accordance with the charges on the plates.

Let us say the polarity on the plates *M* and *M'* is such that the electronic stream is deflected upwards and on the other pair, which are at right angles to *M* and *M'*, the polarity is such that the beam is pulled to the right. This will make the spot of light on the fluorescent screen, *F*, in the tube's end move towards the upper right side of the tube. It may be said generally that the electrons are set free from a hot cathode at *C*, by means of a heated wire filament in the same manner as in a vacuum tube. *A* is the anode on which there is a positive charge and in the center of which is a small hole, and *B* is a second anode which serves to speed up the electrons.

It was explained previously that in order to create an image at the receiving end of a television system, the object at the transmitter must be "scanned"; this, meaning that every point of the object's surface must be passed over and illuminated by a spot of light. This spot of light travels from top to bottom and from side to side. The electronic stream at the receiver must be deflected in the same way and this is done by means of the four plates. The brightness of the electronic spot of light on the fluorescent screen is controlled by the amount of negative bias that is impressed on the control electrode, *CE* in *Fig. 96*. This, of course, is dependent upon the amount of light that is reflected from the "object" to the photoelectric cells at the transmitter. Thus, besides the varying current which is placed on the carrier wave from the photoelectric cells at the transmitter, a current must be broadcast that will govern the speed at which the electronic stream is moved back and forth and up and down across the fluorescent screen.

It is claimed that this system of television has greater advantages than the one employing the scanning disks, for there are fewer moving parts that must be kept in synchronism. However, the cost of the apparatus for the cathode-ray system is much in excess of the other, and the life of a cathode-ray tube is comparatively short, when compared with that of amplifier vacuum tubes, for instance.

The Peck Television System.—The interesting feature of this system is at the receiver and consists

of a disk in which are fixed sixty reflecting spherical lenses evenly spaced near the edge. These lenses are not spheres, but half spheres with the flat surfaces silvered. Each lens is set at a different angle with the horizontal, so that light from a certain

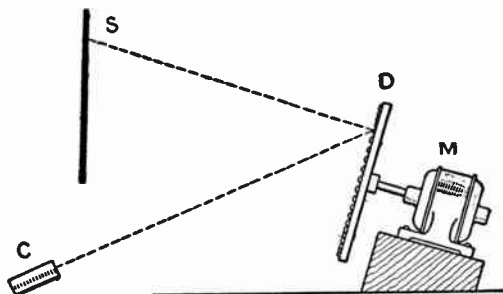


FIG. 97.—C, the crater neon lamp directs its light energy to the disk, D, from which it is reflected to the screen, S, on which the television image is built up.

point will be reflected at a certain angle by each lens.

In *Fig. 97* is shown a diagram of how this system is set up. C is a crater-type neon lamp, which directs its varying-intensity beam at a particular point on the disk D, in which are mounted the spherical lenses. S is a special screen on to which the light from the lenses is reflected. As the disk rotates, the light from C is reflected from each lens in turn and falls on a different part of the screen than did the one before it. This means that in a complete revolution of the disk, the light from C sweeps across the screen sixty times. During each passage of the light it is varied according to the light that is re-

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flected to the photoelectric cells at the transmitter, and so the transmitted image is formed on the screen.

It is claimed that with this system there is an absence of the black horizontal lines, usually seen with disk reproduction. Also, the image can be enlarged by placing the screen further from the disk, notwithstanding that this results in a lessening of the light.

CHAPTER XXVII

RADIO IN OTHER FIELDS

TO-DAY the use of radio apparatus is not confined to the field of broadcasting speech and music alone. Many different fields have found the various components of radio reception and transmission valuable in either lightening or developing their work.

For instance, consider the field of the talking motion picture. If progress had not been made in the development of audio-frequency amplifiers, pick-up devices, photoelectric cells and loud speakers, the "talkies" would never have reached the stage they have attained to-day.

Of course, due credit must also be given to the research workers in the film and phonograph fields, but more than to any one other piece of apparatus credit of achievement has to be awarded to the vacuum tube, which made all this possible.

Let us briefly trace the various uses to which radio is put in this field. Whether the sound be recorded on the film or on a phonograph disk, a microphone with audio-frequency amplifiers is employed in the studio. If the "sound-on-film" system is employed, as it is in the R.C.A. *Photophone* and De Forest *Phonofilm* systems, then in the reproduction in the theater photoelectric cells are used to transfer the light energy picked up from the film into electrical

energy that is amplified by a-f. power amplifiers in the operator's booth and fed to the loud speakers behind the screen on the stage. These same amplifiers are used if the sound is recorded on a phonograph disk. Here mechanical energy is transferred into electrical energy by means of a magnetic pick-up device, which was developed primarily for use in combination radio-phonograph outfits.

Loud speakers for theater use have grown up from the radio instrument, with which we are familiar. If the output of an amplifier that is used in a theater were fed into the ordinary speaker that is used in the home, the blasting effect would be tremendous; in fact the diaphragm in some cases has been split apart by the violent movement of the armature or moving coil. Developments in exponential horns have been made so that now horns of 6 to 12 feet effective length are in use with electrodynamic speakers. It has been found that the use of horns in theaters has bettered the control of the sound as it is sent into the auditorium. The sound can be directed, either up or down, or to the side, thus reducing echoes and troublesome reverberations.

Television.—Whenever anyone mentions the subject of television it is generally dismissed with the remark, "Oh, that is four or five years distant." This may all be true, but at the present time three stations are broadcasting television signals on regular schedules, and by the time this book is published there will be available television receivers.

A word of warning might not be amiss here. Those who say that television is several years distant

are partially correct, if they mean television in a state of perfection parallel to speech broadcasting as we know it to-day. That is perfectly true. However, the receivers that have been promised for the near future may be likened to the broadcast receivers of 1923. They will produce silhouettes in movement and that is not such a long step from halftone television. It will give the amateur worker something to think about and work on.

The very nature of television closely links it with radio—in fact, it really is seeing by radio. The usual broadcast equipment is used, with the exception that instead of a microphone picking-up sounds made in the studio, photoelectric cells pick-up light energy and transform it into electrical energy, which is used to modulate the transmitter's carrier wave. The light coming from the object whose image is being put on the air, is broken up or *scanned* by means of a rapidly revolving disk, which has a number of small holes drilled in it in spiral form.

At the receiving end a regular short-wave receiver is used for picking up the signals. They are amplified in their radio-frequency state, detected and again amplified in a resistance-coupled a-f. amplifier. Instead of a loud speaker in the output of the amplifier, there is a neon tube, between which and the eye of the spectator revolves a similar disk to the one in the broadcast station. These two disks must be rotating at exactly the same speed, in synchronism, and if they are then we see built up on the plate of the neon lamp an image of the object before the transmitter.

Neon tubes are in general use in television receivers, for they possess the property of responding instantaneously to any changes in current that may be impressed across their terminals. The characteristic color of a neon tube is a brick red, so that we see in a television (as the receivers are called) a picture in movement of the object in blacks and reds.

Mr. D. Macfarlan Moore of the General Electric Company has developed a neon tube that will project its rays on a screen, this being called a *crater* type of neon tube. With a tube of this type in the receiver the image picked-up by the set can be thrown on a screen aided by a system of lenses, so that a roomful of people may see it.

Still more recent developments are those of the engineers of the Bell Telephone Laboratories. They have succeeded in transmitting outdoor scenes with excellent clarity and, more remarkable still, television in natural colors. This last development makes use of another tube at the receiving end—one filled with argon gas instead of neon. This gas glows with a bluish color and with the aid of suitable color filters images of objects such as a section of a watermelon, a pineapple, and a girl in a multi-colored dress, were transmitted with no loss of color or detail.

Photoelectric cells are used in many other places to-day and work is being constantly pursued to find new uses for them. In a New England town the street lights are turned on in the evenings and off in the mornings through the media of photoelectric cells. When the sun sets and the light thereby lessens the current produced in the cells is changed,

which operates a delicate relay and which in turn causes an electrically-controlled switch to turn on the lights.

Then these cells are used in any type of selecting device where color is the prime consideration. Many different fruits and beans are graded by color and it has been discovered that photoelectric cells can detect slighter differences in shades of color than can the human eye.

In these selecting devices a bright line shines on the oranges, we will say, as they come along a trough. Above them is a photoelectric cell, which receives the reflected light from the oranges. If a dark one comes along, the current in the cell changes, operates a relay, which causes an arm to push the orange into another trough.

Photoelectric cells can also be used in the determining of the proper mixtures of chemicals, generally in liquid form, in which case the light is transmitted through the mixture and is not reflected.

The author recently witnessed a demonstration of how a photoelectric cell could be used to control a radio receiver. A cell was installed in a set and so connected that when a ray of light fell upon it, the set could be turned on. By diminishing the amount of light falling on the cell, the volume of the output could be controlled. In fact, the use of these wonderful cells in industry is still in its infancy and many new uses are possible.

Radio in Aviation.—To-day the great cry in aeronautical circles is "Safety," and to no better agency can aviators turn than radio. Up to the

present time radio has given the airplane a compass by which the pilot can determine if he be on his course and also a means of communicating with the ground while he is in flight. Short-wave transmitters and receivers are used for communication, as the apparatus is well adapted to the space and weight limitations of a plane.

One of the most interesting developments of radio in the aeronautical field is the radio altimeter. This device, developed by Dr. E. F. W. Alexanderson of the General Electric Co., indicates exactly the height at which the pilot is flying. Heretofore, altimeters operating on the principle of barometers have been in general use, their great drawback being that they were efficient only when the plane was flying over land at sea-level. Otherwise a correction for the number of feet above sea-level had to be made for the particular terrain over which the plane was flying. Then too the action of the barometric altimeter was rather sluggish.

The radio altimeter, on the other hand, indicates instantaneously the height of the plane. The reflection of radio waves is the principle upon which it operates and thus it makes no difference how high above sea-level the land is. There is a constant-frequency oscillator sending out a wave from the plane towards the ground. When this wave reaches the ground it is reflected back up to the ship and there received, a meter indicating to the pilot the number of feet he is above the terrain over which he is flying. This device is particularly valuable when the pilot is landing on unknown ground or at night

with no lights, as it operates efficiently to within a few feet of the ground. In fact, it is so sensitive that it will indicate the change in altitude due to the ship flying over a house of medium height.

Another valuable radio device is the one which shows the pilot whether he be on or off his course. Use here is made of the *beam* system of transmitting signals, which means that instead of the waves being sent out in all directions they are concentrated like the beam of a searchlight. A short-wave receiver in the plane indicates to the pilot by means of the loudness of the signals in his headset whether or not he is following his course. This system also operates a visual indicator for the pilot.

One of the most recent achievements in communication between an airplane and the ground was when two-way communication was established between a plane flying in the vicinity of northern New Jersey and London, England. This was done by means of a short-wave transmitter and receiver in the plane, the signals of which were picked-up at Whippany, N. J., sent by land wire to a short-wave transmitter in New York City, received at Baldock, England, and then by land wires to London. The return circuit was by land wires from London to Rugby, where a short-wave transmitter put the signals on the air. They were received at Netcong, N. J., sent by land wires to Whippany, where they were again put on the air for the person talking in the airplane to pick-up.

CHAPTER XXVIII

RADIO AND TALKING MOTION PICTURES

WHEN music, speech, and other sound effects were added to the moving pictures, the men who were responsible for this development borrowed a great deal of their apparatus from the radio field. The microphone, the audio-frequency amplifier, the loud speaker—these and more were developments of experimenters who were at the time concerned with getting better results in the broadcast field.

Sound is synchronized with motion pictures by two methods: the sound-on-disk and the sound-on-film. The former, being the one method of recording sound that was better developed, naturally was given preference at the start, but it had disadvantages and is gradually becoming obsolete for theater uses.

Sound-on-Disk Reproduction.—The process of cutting sound grooves on phonograph disks is a very complicated one, requiring great care, both during the cutting and in the preparation of the records afterwards. The records used in connection with motion pictures are 16 inches in diameter and the turntable instead of rotating 78 r.p.m., as is usual in home talking-machines, rotates $33\frac{1}{3}$ r.p.m. An electromagnetic pick-up is used instead of the

phonograph sound-box and the small currents from this device are amplified by means of an audio-frequency amplifier, similar to that described in *Chapter XIV*, but with a greater power in the output. The loud speakers are, in general, electro-dynamic units working into exponential horns, by which the sound can be directed to whatever part of the theater necessary so that it will be evenly distributed.

A starting point is marked on the picture film and also on the sound record. Several feet of blank film at the beginning of each reel are left to be threaded through the projection machine and then when the reel in the machine projecting the picture on the screen is nearly finished the second projector is started. The turntable is electrically driven through a flexible shafting by the same motor that operates the picture projector, insuring a constancy of rotation and synchronism. By means of a variable resistance, called a fader, the sound from one projector is decreased and that of the other built up, so that one fades into the other.

The main disadvantage of this method of sound projection is that the records have a relatively short life. The sound waves are cut in the sides of the grooves of the record and the wear of the needle in a short time causes the fine variations of the grooves' width to become flat, and so the record will lose its brilliance. Also, the records have to be shipped with the reels of film and this adds to the cost and trouble for the film exchanges. This method also is more troublesome for the projectionist in

the theater, for, if the needle should jump from one groove to another for any reason, the picture and the sound would be out of step. Also, if there is a break in the film, when it is repaired the same number of inches of film must be replaced as were removed, so that the synchronism will not suffer.

Sound-on-Film Reproduction.—This type of talking motion pictures can be divided into two classifications: those recordings made with a sound track

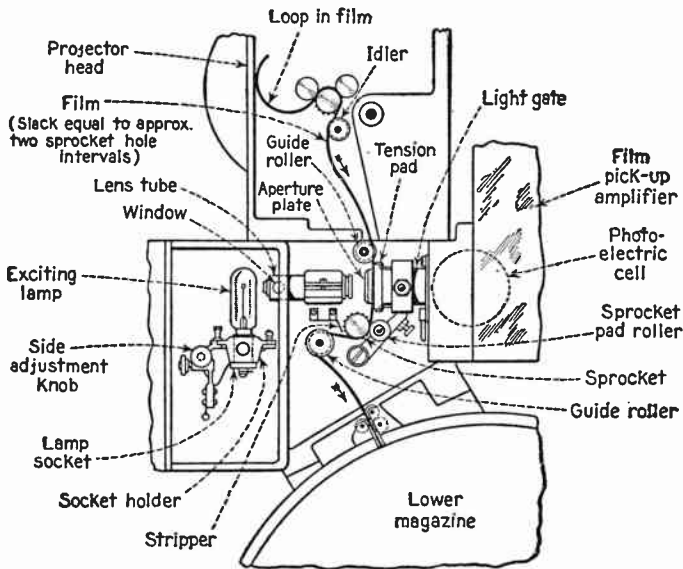


FIG. 98.—“Sound Head” of a projector for talking motion pictures.

on the film that is constant in width and variable in density and those made with a variable width and constant density. The former is generally known as the “Movietone” and the latter method as the

"Photophone" process. The method of reproducing the sounds recorded on the film tracks are identical, the only difference being in the recording.

In *Fig. 98* will be found a diagram of the apparatus in the so-called "sound head" of a projector, and its relation to the projector as a whole. In *Fig. 99* is a diagram of the essential parts of the sound head.

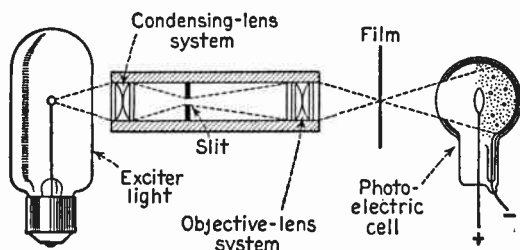


FIG. 99.—The essential parts of the sound head.

At the left is the exciter light, which gives off light energy from a single filament that is horizontal. This filament is placed at the focus of the condensing-lens system at the left end of the optical system. At the right-hand focus of this lens system is placed an aperture plate in which there is a knife-edge slit that is 0.001 inch wide. The light passed by this slit is picked up by the second lens system, called the objective, and focused on the sound track of the film. The density or width, depending on the system of recording used, varies the amount of light that is passed through the sound track of the film on to the photosensitive surface of the photoelectric cell at the right. It is in this device that

the light energy is transformed into electrical energy. The output of the average cell is measured in microwatts (millionths of a watt) and so a great amount of amplification is necessary before the currents are large enough to actuate a group of loud speakers. A photoelectric-cell amplifier (commonly known as the PEC amplifier) amplifies the output of the cell before it is of sufficient magnitude to actuate the input of the amplifier that is used in conjunction with the electro-magnetic pick-up, described in connection with sound-on-disk reproduction. Some idea can therefore be gained as to the minute currents in the photoelectric cell's circuit.

This system of reproduction demands the greatest care on the part of the projectionist, for all the adjustments of the sound head and associated apparatus must be made correctly or the sound as reproduced from the loud speakers will not be natural nor a faithful reproduction of the sound as recorded on the sound track of the film.

The photoelectric cell is described in *Chapter XXIX* and so merely its use in connection with sound reproduction is considered at this point.

The loud speakers that are in general use in theaters where talking motion pictures are exhibited are of the electrodynamic type, as was mentioned, because they are capable of handling large amounts of power and radiating to the audience undistorted sound waves of great intensity. It is necessary to direct these sound waves to certain parts of the auditorium or else there will be sections of the audience who will be unable to hear with ease what is being

reproduced. This matter of directing sound and controlling it after it has been directed into an auditorium is one of the most intricate engineering problems connected with the theater. For example, the behavior of sound waves coming from loud speakers will be entirely different when the seats of the auditorium are filled than when they are empty, due to the sound waves being reflected from the empty chairs. Also the sound waves impinging on bare walls will be reflected to certain parts of the auditorium and persons seated there will be annoyed by unpleasant echo effects. Therefore, the acoustical engineer must see that the sound leaves the loud speakers with the proper intensity and direction so that the patrons will not be disturbed by echoes or reverberations.

The loud speakers are placed behind the screen on which the motion pictures are projected. This is another problem which the talking motion pictures brought forward—the proper type of screen. The first and foremost function of a screen is to reflect as much of the light projected upon it as is possible and in order to make the illusion of sound emanating from the actors' lips on the screen the loud speakers have to be located behind it. Unless the screen be made of a porous material, this illusion can not be maintained. On the other hand, if the screen has sufficient openings for the sound to pass through unimpeded, then there will be insufficient light-reflecting surface. A compromise has been effected and two or three screens developed in which there are minute openings for the passage of the

sound and in which the reflecting surface has been made as efficient as possible.

Recording Sound on Film.—The processes used for recording the sounds on the narrow track on the film are interesting, as radio apparatus is used to a great extent. As the width of the sound track is 0.1 inch (on 35 mm. film) and as the variations are very slight, it may be seen that the recording apparatus requires the most delicate adjustments and handling.

When a film is being run through a projector in a theater, it passes through at a speed of 90 feet per minute; therefore, it must be exposed at the same rate. This is especially true of sound-on-film recordings, for if the film is not run through the projector at the same speed at which it is exposed, then the frequencies will not be reproduced as they were originally. The effect of a film being run through the sound head at a slower speed than normal will sound similar to a phonograph when it needs winding, all the frequencies will be lowered.

First, consider the recording of the constant width-variable density type. This is in general done on another film than the one on which the pictures are being photographed, because of the different requirements in the developing technique, and afterwards the sound track and the pictures are printed on the same film.

One of the most ingenious pieces of apparatus that is used in the talking motion picture field is the so-called light valve, which is used in the recording of this type on the sound track. It consists of a duraluminum ribbon .006 inch wide and .003 inch

thick that is formed into a loop and the sides of which lie in a fairly strong magnetic field. The sides of this ribbon are so arranged that they are directly over a tapered slot and they are held by clamps within a distance of .002 inch of each other. The ends of this loop of ribbon are connected to the output terminals of the amplifier for stepping-up the output of the microphone, that picks up the speech of the actors. The varying currents in the ribbon set up a second magnetic field and the interaction of these two fields causes the ribbons to vary their distance from each other according to the current flowing.

The unexposed film is passed before this light valve through which a strong light is shining, it being concentrated on the slot through a system of lenses. In order for a note of a certain frequency to be recorded on the sound track of the film, the light valve must be opened a certain amount and closed a certain amount. This variation in the amount of light that passes through the light valve must occur within a certain time for a note of a certain frequency. If the note has a frequency of, say, 6,000 cycles per second, and as the film passes through the camera at the rate of 90 feet per minute, which is equivalent to 18 inches per second, then if the beam of light controlled by the slit be .0015 inch wide and if we must have a dark space and a light space to form one complete cycle of a sound wave, then by division the space occupied by one cycle of a 6,000-cycle note is .003 inch along the sound track. These figures are given to illustrate how fine

the adjustments have to be. A sketch of a constant width-variable density sound track is shown in *Fig. 100A*, the sound track appearing as a series of lines of different thicknesses.

In *Fig. 100B* is shown the sound track only of a constant density-variable width sound track. This type of recording is done with a constant source of light shining on a very small mirror that is suspended between two fine metal ribbons, which in turn are suspended in a magnetic field. When a varying current from the output of the microphone amplifier

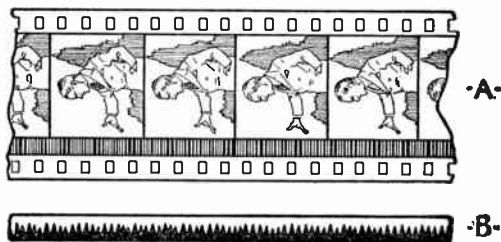


FIG. 100.—A portion of film showing two types of sound track. At A is the constant width-variable density type, and B is the constant density-variable width type.

is sent through the suspended ribbons that are one continuous circuit, the field set up reacts with the constant field in which the ribbons are suspended, and the mirror turns according to the strength of the current. The light energy from the source, previously mentioned, is concentrated on a small spot and this is reflected to the sound track of a film that is passing at 90 feet per minute through a camera. The movements of the mirror cause the light spot to move back and forth on the track, producing the

saw-tooth effect in *Fig. 100B*. These variations in density are exact duplications of sound waves, and when run through a sound head will produce the same variations in light intensity as will the lines of varying thickness shown in *Fig. 100A*. It is because of this similarity that either of these two processes can be run through the same projector with identical results.

The technique of recording has undergone great improvements recently: mainly, the idea borne in mind has been fidelity of reproduction, not only of speech and music, but of incidental noises that must accompany a picture to make the illusion as natural as possible. Musical sounds have a range of approximately up to 4,000 cycles per second, without taking into consideration the harmonics or overtones that are about double. In the past just a little more than 6,000 cycles were recorded and as a result, the early sound pictures were far from natural. However, it is now possible to record with good results 9,000 cycles per second, thus insuring practically lifelike sounds.

On the other hand even if it were possible to record 15,000 cycles, if the rest of the apparatus used in reproducing the sound were not capable of reproducing these high frequencies, the effort would be worthless. Amplifiers and loud speakers have definite limits of frequency response, but taken all in all the apparatus to-day is capable of faithfully giving to the audience a large percentage of the sounds that they are used to hear.

CHAPTER XXIX

THE PHOTOELECTRIC CELL AND ITS USES

It may be surprising to many to know that photoelectric effects were being studied quite a number of years before the advent of the vacuum tube. In 1887 Heinrich Hertz, while experimenting with a spark gap, found that the ultra-violet light from one gap had a decided effect on the behavior of a second gap. And even before this—in 1873 to be exact—it was accidentally discovered that the element selenium changed its electrical resistance under the influence of light.

Interesting as the history of the gradual development of photoelectricity is, we are here concerned with the photoelectric cell, its theory and some of its manifold uses. The vacuum tube has been described by many flattering terms and it is truly a wonderful device, but the photoelectric cell can do many things which the vacuum tube amplifier can not do and which seem to be remarkable, for the reason that the cell can for certain purposes practically take the place of the human eye.

Light into Electricity.—The function of a photoelectric cell is to transform light energy into electrical energy. In other words, when no light is falling on the photosensitive surface (the cathode) of a cell,

it may be assumed that no current is flowing from the anode out into the output circuit. When a light is permitted to fall on the cathode, a current can be detected in the output circuit and the more intense the light the greater will be this current. Let us consider the cell's action in some detail.

It will be remembered that it was stated previously that electrons could be liberated from a substance by heating the substance, as was done in the case of the filament of a vacuum tube, or by collision. We now come to a third method. When light comes in contact with certain substances, they emit electrons in proportion to the intensity and color of the light. According to the latest theories advanced by scientists, light possesses a certain amount of energy, the unit of which is called a quantum, and the more intense the light the greater the number of quanta.

Experimenters in photoelectricity found that the metals of the alkali group (lithium, sodium, potassium, rubidium, and caesium) have the property of emitting electrons when light that is visible to the human eye, as well as the so-called invisible light, falls upon them. From the structure of the atoms of these metals it was found that there were one or more electrons in each atom that were not as much under the influence of the positive nucleus as the others. Therefore, when light impinged on one of these alkali metals, the energy possessed by the light was transferred to the electrons in such a way that they became detached from their parent atom and went out into space. These electrons having a

negative charge, of course would be attracted to a positively-charged body, in the same way that the electrons emitted by the filament of a vacuum tube travel to the plate, which is positively charged with respect to the filament.

Summing up, light can be considered to be a series of drops of energy that is raining upon the light-sensitive surface of a photoelectric cell. Every time one of these drops of energy, a quantum, encounters an electron, the latter is released from the atom of metal with a certain amount of energy, which it uses to move towards the anode.

The Structure of a Photoelectric Cell.—Let us see how this theory applies to the photoelectric cell. In *Fig. 101* is a diagram of a photoelectric cell. It

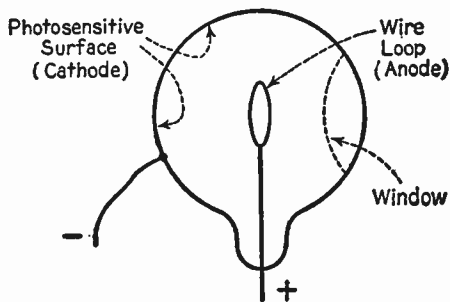


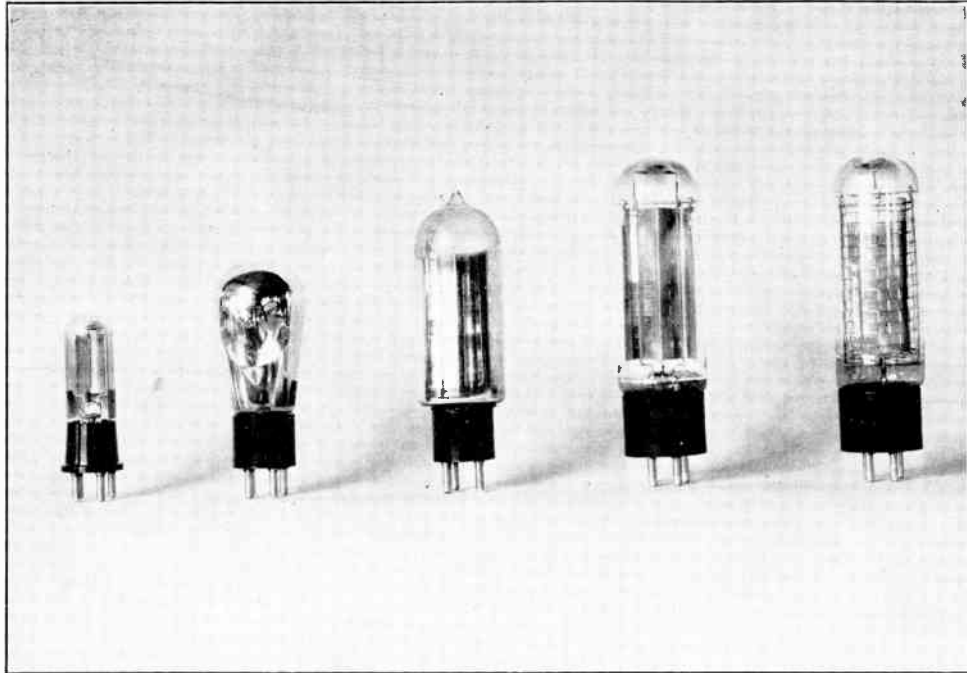
FIG. 101.—Light energy impinging on the cathode through the window of the cell liberates electrons which travel to the anode, on which there is a charge, making it positive with respect to the cathode.

consists of a glass bulb, which is either spherical or cylindrical, on the inside of which is a thin coating of the alkali metal (sometimes over a coating of

silver to insure good conduction of the currents). In the center of the cell is a loop or straight piece of wire, which is the positively-charged anode. Both the cathode and the anode are connected by wires to the prongs in the base of the cell, so that connections can be made to them from the external circuits. In one side of the glass bulb the coating is removed so that the incoming light will have unimpeded access to the photosensitive surface.

It might be stated in passing that there are several methods of depositing the cathode on the interior of the glass bulb. The method which produces very sensitive cells is one where hydrogen is introduced into the bulb at a low pressure after the potassium, for instance, has been deposited on the glass. An electric potential of about 300 volts is applied between the anode and cathode, resulting in a discharge between the elements through the hydrogen gas. This changes the chemical make-up of the potassium, making it more sensitive photoelectrically. The hydrogen is pumped out and an inert gas (one that will not react with the potassium) is introduced, this gas being sometimes argon, one of the gases present in small quantities in the air.

One of the most sensitive cells yet devised is the caesium-oxide cell developed by L. R. Koller. Not only is this cell sensitive to the shorter wavelengths of light (those colors in the blues and violets) but it is also quite sensitive to the reds. By sensitivity is meant the amount of current that will flow for a given amount of light of a certain color impinging on the cathode.



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Different types of photoelectric cells which show the construction of the anode and cathode.

High-Vacuum and Gas-Filled Photoelectric Cells.

—When a given light ray of a certain color impinges on the cathode of a cell, a certain number of electrons are released from the cathode and go to the positively-charged anode. It is important that their path between the cathode and the anode be as free from obstructions as possible, so that the resistance will be low and likewise the consequent losses. For this reason, all the molecules of air that possibly can be removed from the interior of the glass bulb are pumped out after the photosensitive surface is prepared. Such tubes having a comparatively small amount of gas in the bulb are called high-vacuum photoelectric cells.

On the other hand, it was found that when some gas of a nature that did not react with the chemicals of the cathode was left in the cell, that the current from the anode was greater for a given amount of light than it was when a high-vacuum cell was used. The reason advanced for this action was that when the electrons in their journey from the cathode to anode encountered an atom of the gas, the resulting collision liberated another electron, which in turn went towards the anode. Perhaps this second electron collided with another gas atom and a third electron joined the other two. Of course, the more electrons coming to the anode and so going out to the external circuit meant an increase in current output. Therefore, the gas introduced into the cell really supplies additional electrons, which are called secondary electrons, as they are the result of collisions by the primary electrons emitted from the

cathode due to the action of the impinging light energy.

Action of a Photoelectric Cell.—In *Fig. 102* an electric lamp, *L*, is powered by the battery and the current going to the filament can be regulated by the rheostat, *R*. *P* is a photoelectric cell with its window opposite *L* and to its cathode, *C*, is connected the negative side of the battery, *B*,

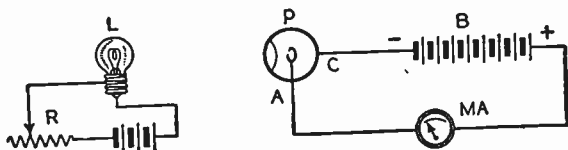


FIG. 102.—Light energy from the lamp, *L*, can be varied by the rheostat, *R*, as well as the distance between *L* and *P*. Note that the positive terminal of the battery is connected to the anode, *A*, of *P* and the negative side to the cathode, *C*.

the plus side of which is connected to a microammeter (measuring millionths of an ampere). The anode *A* of the cell, *P*, has impressed on it a positive potential from *B* through the microammeter, *MA*.

Let us assume that all the resistance of *R* is cut out so the lamp *L* will give out as much light energy as possible. This will pass to the photoelectric cell, *P*, and be received on *C*, the cathode as a certain intensity of light. This intensity will vary with the distance *P* is from *L*, the proportion being the square of the distance; that is to say, if an intensity of perhaps 10 lumens is reaching *C* when *P* is 1 foot from *L*, if the distance be increased to 2 feet then the intensity will drop to 2.5 lumens. Let us assume

further that with 10 lumens the microammeter will read 20 microamperes.

Now resistance is introduced in the filament circuit of *L* by cutting in some turns on the rheostat and the light energy passing to *P* is reduced. This will result at once in a reduction of the current indicated on *MA*. The more resistance that is cut into the circuit of *L*, the less light will fall upon *C* and as a result, the less current will flow through *MA*. The same reduction in current could be obtained by keeping the light source constant and increasing the distance between *L* and *P*, as was mentioned above.

However, this will show that the less light that impinges on *C* will result in a smaller flow of electrons to *A* and so a smaller current in the output, as indicated on *MA*. This action can be thought of in terms of an increased resistance between *C* and *A*; the less light coming to *C*, the greater is the resistance in the *C*-to-*A* circuit, and therefore, the less current flow. The amount of voltage in the battery *B* is of importance and the value recommended by the manufacturer should never be exceeded. If it is, it is liable to reduce considerably the useful life of the cell.

Utilizing the Photoelectric Cell.—The output current of a photoelectric cell is measured in microamperes, which is an extremely small unit. (For example, the current consumption of the filament of a 201-A vacuum tube is 0.25 ampere, which is equivalent to 250,000 microamperes.) Such a minute current and a consequent small voltage must be amplified before it can be put to any useful work, so the output of a cell can be connected to a circuit

such as is shown in part in *Fig. 103*. This will be recognized as a combination of resistance and transformer coupling as described in *Chapter VIII*. The necessary anode voltage is impressed on that element *A* of the cell *P* through the resistor, *R1*, the negative terminal of that battery being connected to the

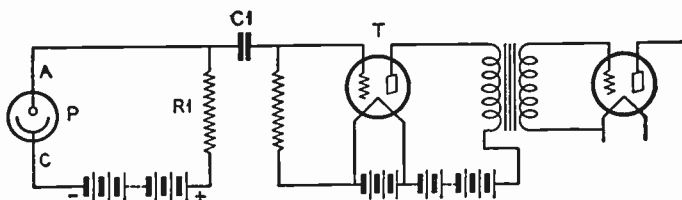
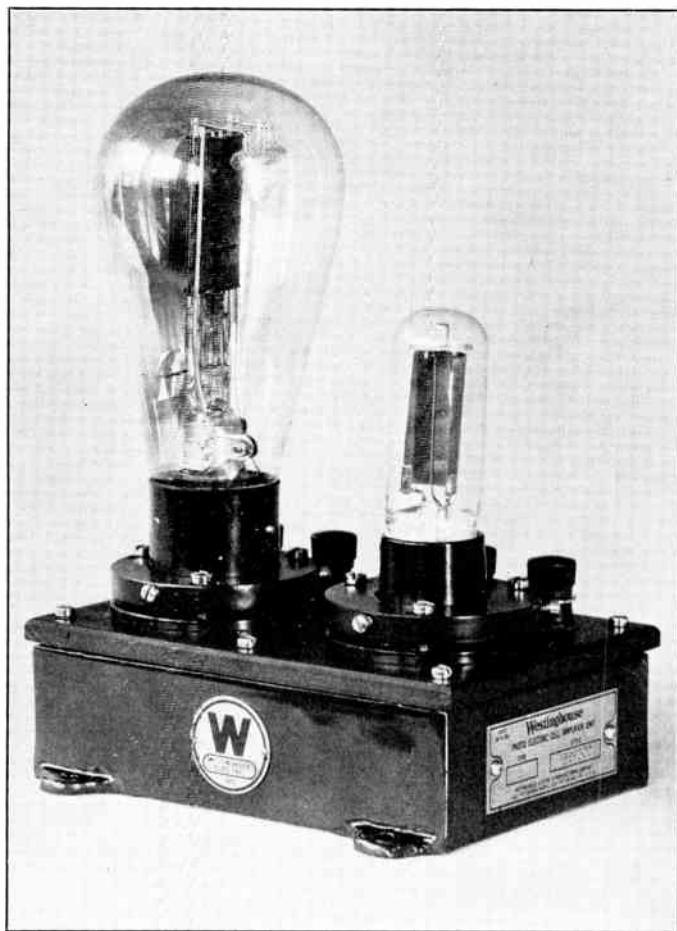


FIG. 103.—Circuit for amplifying the output of a photoelectric cell, so that the current will have sufficient strength to actuate a relay.

cathode, *C*. The *variations* of the current coming from *A* act on the condenser, *C1*, like alternating current and charge and discharge *C1*, producing a varying voltage on the grid of the amplifying tube, *T*. The output of this tube is connected to an a-f. transformer through which the voltage is further amplified by one or more stages if necessary.

Of course, the use to which the current from the photoelectric cell is to be put will determine the type and amount of amplification necessary. If the cell is being used in conjunction with the reproduction of sound-on-film motion pictures, then a great deal of amplification must be introduced before the currents are of a sufficient size to actuate the loud speakers. Also the amplification must be carefully controlled to see that no distortion enters. However, when cells are used for controlling the



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Photoelectric cell and amplifying vacuum tube incorporated in an amplifier, which is capable of operating a relay for remote control operations.

the grid of T negative with respect to the filament, which bias has been established by the setting of $R1$ and the value of the battery C . Thus, no current—or perhaps a minimum current—will flow through R . If light energy be allowed to impinge on the cathode of P , then a certain current will flow in accordance with the intensity of the light. This current will flow because of the positive potential impressed on the anode from B , through R and MA , with its return circuit through B , a portion of $R1$ and the whole of $R2$. In this latter resistor there will occur a voltage drop, and this is an important point. This voltage, or IR drop, will cause the grid of T to become more positive with respect to the filament, and when this occurs it results in an increased flow of plate current, which was explained previously in *Chapter XVIII*. The increased flow of plate current will mean an increased flow through the relay's coil, R , and this will be sufficient to energize the relay so that the armature will move to the right and close the circuit through A and B . As long as this larger current flows the relay armature can be made to stay towards the right, but when the current is decreased, due to the lessening of the light intensity falling on the cell's cathode, then by means of a spring the armature is released, opening the circuit through A and B .

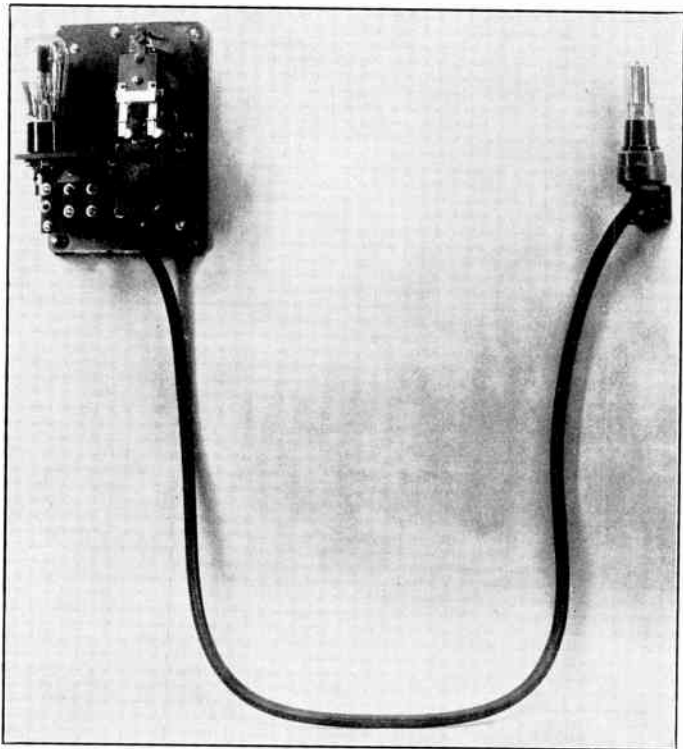
Such a circuit can also be made to function in the reverse manner, *i.e.*, when the light is increased on the cathode, the plate current of T can be made to decrease, thus opening the relay and the A - B circuit.

Practical Uses.—If all the known uses to which the photoelectric cell is put were now to be listed, by the time this book was in the reader's hands, that list would be incomplete. In the research laboratories of every large electrical company experiments are being conducted wherein new uses for cells are being discovered.

In general, the functions of a photoelectric cell can be divided into two groups: starting and stopping operations; and continuous operations.

Under the first classification would be placed counting operations. Here the objects to be counted intercept a beam of light falling on the cathode, and each time the beam is shut off the plate current of a vacuum tube may be made to decrease and so open a circuit through the medium of a relay, which would actuate a counting or tally device. Such objects might be wooden boxes on an endless belt, or barrels. On the other hand, if the objects being counted would reflect light to the cathode of the cell, the light source could be on the same side of the objects as the cell and when one of the objects passed through the beam of light, it would be reflected to the cell, causing a relay to function, as described above, and so actuating a counter. If the objects themselves emit light energy, as is the case of red-hot ingots in a foundry, then the light source could be eliminated.

Photoelectric cells have proven to be accurate when used in counting devices; more accurate, in fact, than a man, because they do not make mistakes. They have been successfully used in counting



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Photoelectric cell with special cable connecting it to its amplifier and relay. This arrangement permits the cell to be used as an exploring "electric eye."

vehicles passing a given point, and in hundreds of different types of factories.

Under this same classification of uses might be placed that of initiating an operation, as opening a door, starting machinery, ringing an alarm, etc., by means of either the interception or impinging of a beam of light on a cell. For instance, one of the latest safeguards used by banks is to have a beam of light passing before the door of the safe. If the light be interrupted, a change will occur in the cell's circuit and an alarm rung. It is also of interest to note that the light need not be visible to the human eye. It can be ultra-violet or infra-red light, which is only visible to the cathode of the photoelectric cell and photographic plates. Therefore, a burglar even though he knew that such a safeguard were in place, would be unable to avoid it, as he would not know where the beam of light was.

Stopping an operation also comes under this head of uses. In paper mills where large rollers press the pulpy mass into thin sheets a break in the paper means an expensive delay, especially if the rollers are allowed to run even for a very short time after the break has occurred. A photoelectric cell on one side of the paper and a light source on the other can be arranged to give immediate notice of a break by ringing an alarm, or, if desired, the power can be shut off and the rollers stopped.

Continuous Operations.—The differences between the two classifications of photoelectric-cell operations are very slight, as an increase or decrease in the anode current of the cell determines the action

of a relay or some other delicate device. However, due to the fact that the cell is influenced by very slight changes in color or light intensity, they can be employed in ways that differ to a certain extent from those already described.

When certain liquids are being mixed, as dyes, inks, etc., the proper proportions are determined generally by the color of the mixture. While some human eyes are quite sensitive to small changes in color, yet the photoelectric cell can detect these same slight variations and without fatigue. Such uses of a cell can be made in the grading of objects by their color, as selecting oranges, bananas, etc., or putting cigars into different groups; in short, almost any job that the human eye can do, the photoelectric cell and its attendant apparatus can do also.

CHAPTER XXX

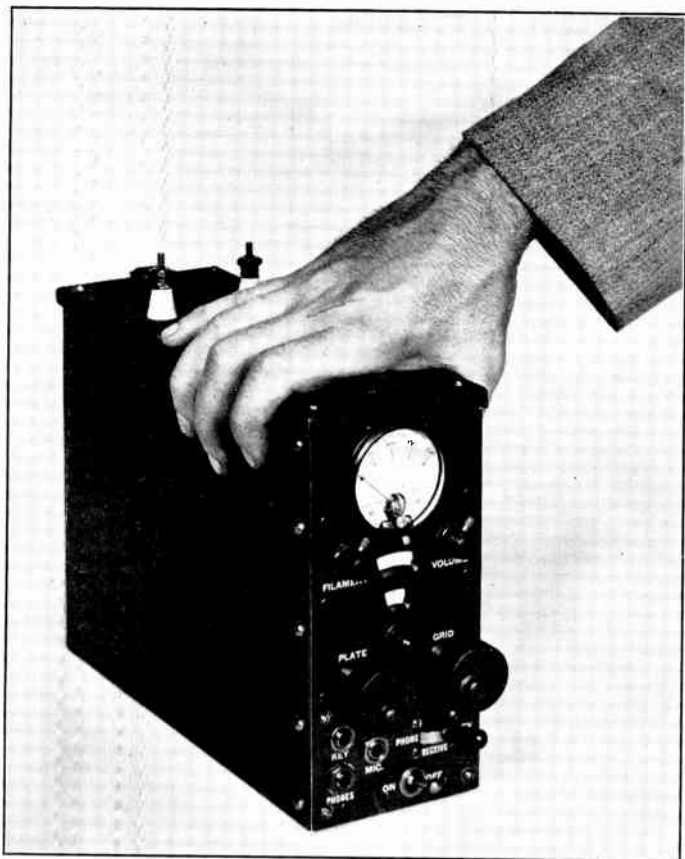
ULTRA-SHORT WAVES

THAT portion of the radio spectrum that lies below 10 meters—or above 30,000 kilocycles, if you think in terms of frequency rather than in terms of wavelengths—is a region that holds great possibilities for the experimenter who likes to tackle something new. Many experimental transmitters and receivers have been constructed for use on these so-called quasi-optical frequencies, but there is still a vast amount of research to be performed before we can lean back in our chairs and say that the job is done.

First of all, quasi-optical frequencies do not behave in just the same way that waves of lower frequencies do; in fact, their behavior is so different that the experimenter has to learn a new technique entirely. For instance in the matter of the waves' travel after leaving the transmitting antenna, they are very directional, going in the general direction in which the antenna is pointing; they do not follow the curvature of the earth; they are not reflected back to the earth again from the Heaviside layer, which is the top of the blanket of air enveloping the earth; obstructions in their path do not make any material difference, as they are not absorbed to any great extent, etc. On the other hand, they can be made to do a great number of things of which

the lower-frequency waves are incapable. They can be reflected and refracted in the same manner as visible light waves; they are very little affected by weather conditions, so that there is a minimum of fading and irregularities in their reception; they can be transmitted with extremely small amounts of power; the apparatus for their transmission and reception can be condensed in a very small space, making it ideal for airplane and automobile communication, etc.

But it is not only in the communication field that experimenters have been busy with ultra-short waves; use has been found for them by the physiologist and the botanist. In some diseases it is necessary to create a fever in the patient in order that the increase in body temperature will combat the malignant bacteria. Heretofore this was accomplished by deliberately giving the patient another disease which would send the temperature of the body up, but now it has been found that if the patient be exposed to ultra-high frequency radiations the body temperature will be increased without resorting to a second disease. The tissue of the body can be destroyed by the use of the so-called *radio knife*, which permits practically bloodless surgical operations. Small animal and insect life can be destroyed, so that vermin extermination is a possibility. On the other hand, plants that have been exposed to ultra-short wave radiations have grown more quickly and larger than those grown under ordinary conditions. In short, the list of possibilities is too long to include in the limited space



RCA Victor Co., Inc.

The 22-pound Transceiver, which is a two-way radio telephone and telegraph transmitter and receiver, is designed for operation on wavelengths under 10 meters, using a super-regenerative circuit and dry-cell tubes.

here, but suffice to state that it is well to bear the fact in mind that ultra-high frequencies have other uses than those for communication of sound and sight, for as mentioned previously, they are excellent media for the transmission of television signals.

However, it is the chief concern of the radio amateur to know about ultra-short wave communication, for this is the phase of the matter in which he is interested, these other matters being more or less by-products. Let us consider some of the main differences in the apparatus and its functionings.

In receivers which have heretofore been constructed it did not make a great difference if certain wires were long or short, whether they ran parallel to other connections or what size they were. When receivers or transmitters for ultra-high frequencies are being constructed, these hitherto minor matters become very important. In fact, if certain leads are too long or the wrong size wire, the set will not function at all. In *Chapter IV* you were told that inductance and capacity reactance were affected by the frequency of the current and it is because of these factors that so much care has to be exercised in the construction of these sets. In receivers designed for broadcast wavebands, inductance coils set for coupling the antenna to the radio-frequency amplifier stage had perhaps 50 or 75 turns of wire; in the sets for receiving 5 meters, we have perhaps one or two turns of the copper conductor, and in some cases perhaps even a fraction of a turn. Where 23-plate variable condensers were employed in apparatus for the reception of stations operating between 200

and 500 meters, there are two or three plates in those for ultra-high frequency apparatus. It makes comparatively little difference whether certain tubes be used in receivers for the broadcast band, but in these receivers only certain tubes can be used and in some cases the bases have to be removed in order that the capacity effects of the leads from the tube's elements down to the ends of the prongs will be eliminated.

Such are some of the difficulties that the amateur will encounter when he starts working under 10 meters, but he will find them conquerable. He must exercise more care, and more thought must be given when he is building apparatus for use in this region, but even so he will gain a greater satisfaction for he will be experimenting with radio waves of a kind about which not a great deal is known and there is a chance—and a good one—that he may discover something of great value to his brother amateurs.

While the apparatus used for the transmission and reception of high-frequency waves must be built with great care, yet the parts used are of extreme simplicity. The variable condensers have only a few plates, the inductance coils only a few turns, the vacuum tubes are few in number, but everything that goes in the set should be of high quality. When frequency is measured in millions of cycles, then the insulation of resistors, condensers, and connections becomes important. Losses that are negligible at broadcast frequencies, for instance, assume large proportions at 56,000 kilocycles.

It is quite difficult to specify exact constants for the apparatus of a receiver or transmitter for use on these ultra-short waves, because of the many variations that are probable in constructing a set. In most cases it is simply a matter of cut and try, always keeping in mind the primary requirement for short leads and these so located that they can not cause trouble. In both transmitters and receivers radio-frequency choke coils are a necessity, these being in leads that connect batteries to the elements of tubes. Fortunately these chokes are easily constructed, generally consisting of about 30 turns of a fairly small size wire, perhaps No. 36 B. & S. gauge, wound on a form about $\frac{1}{2}$ inch in diameter. Of course, if the chokes are in the filament battery leads, then they should be wound with a larger wire, so that the resistance drop will not be excessive.

In *Fig. 106* will be found the schematic diagram of a receiver that will operate on 5 meters. The three inductances, $L1$, $L2$, and $L3$, are of but one turn each, which is about 3 inches in diameter. The variable condensers, $C1$ for tuning, and $C3$ for regeneration control, can be small compensating condensers, generally having a capacity of about 30 mmf. It may be necessary to remove some of the plates from even these small condensers in order to get the set to function within the 5-meter band. In order to reduce bothersome body capacity to a minimum, extension shafts are placed on the condensers, these shafts being of bakelite rod. It is also well to place the variable condensers and the coils, which are generally mounted directly on the condensers to

reduce length of leads, well to the rear of the set. The bakelite extension rods on the condensers make this easy to do.

It was mentioned above that the capacity effects of the leads within the tube sometimes prevented the set from functioning as it should. With the new tubes that are available to-day, this capacity effect may be overlooked. If the '30 type tube be used in this set, it is unlikely that trouble will be experi-

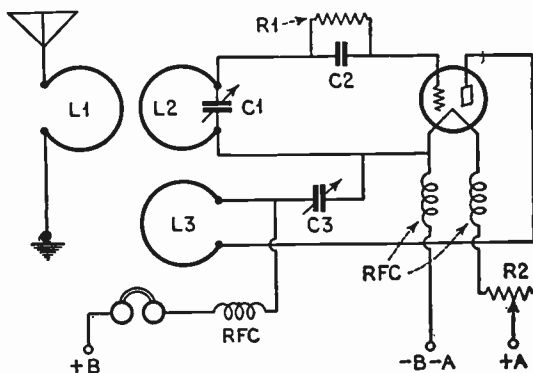


FIG. 106.—Schematic diagram of a 5-meter receiving set.

enced from this source. The filament and plate voltages have not been indicated on the diagram, in case other tubes are used, and for the same reason the size of $C2$ and $R1$ have not been shown. The last mentioned two components generally are of about the same values as used in other sets. $R2$, of course, depends upon the type of tube used and also upon the voltage of the filament battery.

An antenna is indicated as well as a coupling coil, $L1$, which also is about 1 turn of wire or tubing, but

5-meter receivers are capable of working well over fairly long distances, perhaps 5 or 10 miles, with neither antenna or ground. If an antenna is used, it need only be about 20 feet long; a greater length than this will not materially increase the volume of the received signals.

A word of caution is necessary about the material of which you form the inductance coils for sets operating on 5 meters. When high frequencies are flowing in a circuit it is essential that their path be as free as possible from resistance, which, when thought of in this connection, is called skin effect. This is because high-frequency currents do not flow through conductors as do lower-frequency currents: they tend to flow near the surface of the conductor and if copper tubing is used instead of a solid conductor, in some cases the losses due to the skin effect will be lessened. However, if no copper tubing be available for the construction of the inductances larger diameter copper wire will serve. Do not forget that in 5-meter sets every bit of wire whether in a piece of apparatus or used as a lead has inductance. It also has capacity in the neighborhood of some other lead or other piece of apparatus. It is such things as this stray inductance and capacity that make it almost an impossibility to give specific directions for the constructing of a 5-meter set.

In planning the layout of the set, the tube should be located between the two variable condensers, *C1* and *C3*, as this will make for short leads. The grid leak *R1* and *C2* should be as near the tube socket as possible. Before placing this set permanently on a

panel and base-board, it might be well to experiment with it and get some idea of how it behaves. Naturally the leads must be soldered even in the temporary layout, but some experience will be gained by this preliminary try-out. Do not expect the receiver to be exactly on 5 meters, or anywhere near that wavelength; it may be nearer 7 or 8 meters. How the wavelength may be checked will be explained later on. This experimentation is one of the

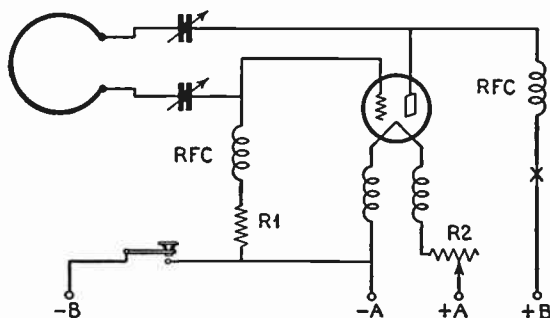


FIG. 107.—A transmitting circuit that will operate on 5 meters.

great incentives for high-frequency work and a great deal can be learned, if it be done intelligently.

If someone in your vicinity is a short-wave enthusiast, he perhaps has a 5-meter set and can help you calibrate yours. If not, then the best thing to do is to connect up a transmitter which will work on this short wavelength. It is not difficult and as can be seen from *Fig. 107* the parts needed are few and inexpensive.

The inductance unit is approximately 4 inches in diameter and should be of copper tubing for best

results. The two variable condensers can be 50-mmf. midget compensating condensers and the radio-frequency choke coils *RFC* can be the size mentioned above. The grid leak *R1*, can be of the order of about 10,000 ohms, while *R2* as before is dependent on the tube used. A key or switch is placed in the negative plate battery lead, which is connected to the negative *A* terminal. Do not forget the heavier wire necessary in the choke coils in the filament leads. In order to tell if the transmitter be oscillating and for other reasons, it is well to include a milliammeter in the plate circuit at the point marked *X* in the diagram. The size of this meter will, of course, depend upon the current output of the tube at certain voltages impressed on the plate.

Tuning.—How do we know when this oscillator is tuned to 5 meters? This is far from being a difficult problem to solve. Find some location where two wires 25 feet in length can be stretched parallel to each other and about two inches apart. (Naturally these wires must be insulated like an antenna.) One end of this pair of wires is left unconnected and the other end of the pair is connected to an inductance to be coupled to the inductance of the oscillator. Place a piece of bare wire near one end of the pair of wires in such a manner as to bridge them and with a stick move this wire slowly along the pair until you see the meter in the plate circuit of the oscillator move. This will occur when the bridging wire is in certain positions along the length of the pair of parallel wires. The distance between two consecutive points where the meter's needle jumps

is equal to one-half the wavelength at which the oscillator is functioning. This distance multiplied by two will give the wavelength in meters. (One meter equals 3.28 feet.) By varying the setting of the tuning condensers the frequency at which the transmitter is oscillating can be changed until the desired frequency is obtained.

Here we have a known source of high-frequency current and the receiver can now be calibrated. With these two instruments within a comparatively short distance of each other, it is doubtful if an antenna will be necessary. Do not expect to pick up signals on the receiver right away. It may be necessary to readjust the size of the tuning condenser *C1*, which should be smaller in value than *C3*. Do not forget also that the coupling between *L2* and *L3* will affect the receiver's operation, a very slight change in position making a fairly great change in regenerative properties. It might be well to plan to use a tube giving a fairly high output in the oscillator so that sufficient current will flow in the output circuit. If so desired raw a.c. may be used, as this is designed for code work. A power transformer, having a high-voltage tap for the plate voltage and a low-voltage tap for the filament power as secondary, is then necessary.¹

¹ In case the reader wishes to explore this subject further, he is referred to a recent book, *Short Wave Wireless Communication*, by Ladner and Stone, published by John Wiley & Sons, New York. (1933)

APPENDIX

APPENDIX

USEFUL INFORMATION

ABBREVIATIONS OF UNITS

| Unit | Abbre- viation | Unit | Abbre- viation |
|-------------------------|-------------------|------------------------|-------------------|
| ampere..... | amp. | kilometers..... | km. |
| ampere-hours..... | amp.-hr. | kilowatts..... | kw. |
| centimeter..... | cm. | kilowatt-hours..... | kw.-hr. |
| centimeter-gram-second. | c.g.s. | kilovolt-amperes..... | kv.-a. |
| cubic centimeters..... | cm. ³ | meters..... | m. |
| cubic inches..... | cu. in. | microfarads..... | μf . |
| cycles per second..... | ~ | micromicrofarads..... | $\mu\mu f$. |
| degrees Centigrade..... | °C. | millihenries..... | mh. |
| degrees Fahrenheit..... | °F. | millimeters..... | mm. |
| feet..... | ft. | pounds..... | lb. |
| foot-pounds..... | ft.-lb. | seconds..... | sec. |
| grams..... | g. | square centimeters.... | cm. ² |
| henries..... | h. | square inches..... | sq. in. |
| inches..... | in. | volts..... | v. |
| kilograms..... | kg. | watts..... | w. |

PREFIXES USED WITH METRIC SYSTEM UNITS

| Prefix | Abbreviation | Meaning |
|--------|--------------|--------------|
| micro | μ | 1 millionth |
| milli | m. | 1 thousandth |
| centi | c. | 1 hundredth |
| deci | d. | 1 tenth |
| deka | dk. | 10 |
| hekto | h. | 1 hundred |
| kilo | k. | 1 thousand |
| mega | m. | 1 million |

SYMBOLS USED FOR VARIOUS QUANTITIES

| Quantity | Sym- bol | Quantity | Sym- bol |
|--|-------------|--|----------------|
| capacity..... | <i>C</i> | magnetic field intensity.. | <i>A</i> |
| conductance..... | <i>g</i> | magnetic flux..... | ϕ |
| coupling co-efficient..... | <i>k</i> | magnetic induction..... | <i>B</i> |
| current, instantaneous value..... | <i>i</i> | period of a complete os- cillation..... | <i>T</i> |
| current, effective value.. | <i>I</i> | potential difference..... | <i>V</i> |
| decrement..... | δ | quantity of electricity... | <i>Q</i> |
| dielectric constant..... | α | ratio of the circumference of a circle to its diameter = 3.1416..... | π |
| electric field intensity... | ϵ | reactance..... | <i>X</i> |
| electromotive force, in- stantaneous value..... | <i>E</i> | resistance..... | <i>R</i> |
| electromotive force, effec- tive value..... | <i>F</i> | time..... | <i>t</i> |
| energy..... | <i>W</i> | velocity..... | <i>v</i> |
| force..... | <i>F</i> | velocity of light..... | <i>c</i> |
| frequency..... | <i>f</i> | wavelength..... | λ |
| frequency $\times 2\pi$ | ω | wavelength in meters.... | λ_m |
| impedance..... | <i>Z</i> | work..... | <i>W</i> |
| inductance, self..... | <i>L</i> | permeability..... | μ |
| inductance, mutual..... | <i>M</i> | square root..... | $\sqrt{\quad}$ |

TABLE OF ENAMELED WIRE

| No. of Wire, B. & S. Gauge | Turns per Linear Inch | Turns per Square Inch | Ohms per Cubic Inch of Winding | No. of Wire, B. & S. Gauge | Turns per Linear Inch | Turns per Square Inch | Ohms per Cubic Inch of Winding |
|-------------------------------------|--------------------------------|--------------------------------|---|-------------------------------------|--------------------------------|--------------------------------|---|
| 20 | 30 | 885 | .748 | 32 | 116 | 13,430 | 183.00 |
| 22 | 37 | 1400 | 1.88 | 34 | 145 | 21,000 | 456.00 |
| 24 | 46 | 2160 | 4.61 | 36 | 178 | 31,820 | 1098.00 |
| 26 | 58 | 3460 | 11.80 | 38 | 232 | 54,080 | 2968.00 |
| 28 | 73 | 5400 | 29.20 | 40 | 294 | 86,500 | 7547.00 |
| 30 | 91 | 8260 | 70.90 | | | | |

TABLE OF FREQUENCY AND WAVELENGTHS

λ—Wavelengths in Meters. F.—Number of Kilocycles per Second. O. or $\sqrt{L.C.}$ is called Oscillation Constant. C.—Capacity in Microfarads. L.—Inductance in Centimeters. 1000 Centimeters = 1 Microhenry.

$$F = \frac{V}{\lambda}$$

where V is the speed of electromagnetic waves, 300,000,000 meters per second.

| λ | F. | O. or $\sqrt{L.C.}$ | L.C. | λ | F. | O. or $\sqrt{L.C.}$ | L.C. |
|-------|---------|------------------------|--------|--------|-----|------------------------|-----------|
| 1 | 300,000 | .0173 | .0003 | 1,300 | 230 | 21.81 | 475.70 |
| 2 | 150,000 | .0331 | .0011 | 1,400 | 214 | 23.49 | 551.80 |
| 3 | 100,000 | .0424 | .0018 | 1,500 | 200 | 25.17 | 633.50 |
| 4 | 75,000 | .0671 | .0045 | 1,600 | 187 | 26.84 | 720.40 |
| 5 | 60,000 | .0755 | .0057 | 1,700 | 176 | 28.52 | 813.40 |
| 6 | 50,000 | .101 | .0101 | 1,800 | 166 | 30.20 | 912.00 |
| 7 | 42,900 | .1174 | .0138 | 1,900 | 157 | 31.88 | 1,016.40 |
| 8 | 37,500 | .134 | .0180 | 2,000 | 150 | 33.55 | 1,125.60 |
| 9 | 33,330 | .151 | .0228 | 2,100 | 142 | 35.23 | 1,241.20 |
| 10 | 30,000 | .168 | .0282 | 2,200 | 136 | 36.91 | 1,362.40 |
| 20 | 15,000 | .336 | .1129 | 2,300 | 130 | 38.59 | 1,489.30 |
| 30 | 10,000 | .504 | .2530 | 2,400 | 125 | 40.27 | 1,621.80 |
| 40 | 7,500 | .671 | .450 | 2,500 | 120 | 41.95 | 1,759.70 |
| 50 | 6,000 | .839 | .7039 | 2,600 | 115 | 43.62 | 1,902.60 |
| 100 | 3,000 | 1.68 | 2.82 | 2,700 | 111 | 45.30 | 2,052.00 |
| 150 | 2,000 | 2.52 | 6.35 | 2,800 | 107 | 46.89 | 2,207.00 |
| 200 | 1,500 | 3.36 | 11.29 | 2,900 | 103 | 48.66 | 2,366.30 |
| 250 | 1,200 | 4.19 | 17.55 | 3,000 | 100 | 50.33 | 2,533.20 |
| 300 | 1,000 | 5.05 | 25.30 | 4,000 | 75 | 67.11 | 4,504.00 |
| 350 | 857 | 5.87 | 34.46 | 5,000 | 60 | 83.89 | 7,038.00 |
| 400 | 750 | 6.71 | 45.03 | 6,000 | 50 | 100.7 | 10,130.00 |
| 450 | 666 | 7.55 | 57.00 | 7,000 | 41 | 117.3 | 13,630.00 |
| 500 | 600 | 8.39 | 70.39 | 8,000 | 37 | 134.1 | 18,000.00 |
| 550 | 545 | 9.23 | 85.19 | 9,000 | 33 | 151.0 | 22,820.00 |
| 600 | 500 | 10.07 | 101.41 | 10,000 | 30 | 167.9 | 28,150.00 |
| 700 | 428 | 11.74 | 137.83 | 11,000 | 27 | 184.8 | 34,150.00 |
| 800 | 375 | 13.42 | 180.10 | 12,000 | 25 | 201.5 | 40,600.00 |
| 900 | 333 | 15.10 | 228.01 | 13,000 | 23 | 218.3 | 47,600.00 |
| 1,000 | 300 | 16.78 | 281.57 | 14,000 | 21 | 235.0 | 55,200.00 |
| 1,100 | 272 | 18.45 | 340.40 | 15,000 | 20 | 252.0 | 63,500.00 |
| 1,200 | 250 | 20.13 | 405.20 | 16,000 | 18 | 269.0 | 72,300.00 |

TABLE OF SPARKING DISTANCES
In Air for Various Voltages between Needle Points

| Volts | Distance | | Volts | Distance | |
|--------|----------|------------|---------|----------|------------|
| | Inches | Centimeter | | Inches | Centimeter |
| 5,000 | .225 | .57 | 60,000 | 4.65 | 11.8 |
| 10,000 | .470 | 1.19 | 70,000 | 5.85 | 14.9 |
| 15,000 | .725 | 1.84 | 80,000 | 7.10 | 18.0 |
| 20,000 | 1.000 | 2.54 | 90,000 | 8.35 | 21.2 |
| 25,000 | 1.300 | 3.30 | 100,000 | 9.60 | 24.4 |
| 30,000 | 1.625 | 4.10 | 110,000 | 10.75 | 27.3 |
| 35,000 | 2.000 | 5.10 | 120,000 | 11.85 | 30.1 |
| 40,000 | 2.450 | 6.20 | 130,000 | 12.95 | 32.9 |
| 45,000 | 2.95 | 7.50 | 140,000 | 13.95 | 35.4 |
| 50,000 | 3.55 | 9.00 | 150,000 | 15.00 | 38.1 |

FEET PER POUND OF INSULATED MAGNET WIRE

| No. of B. & S. Gauge | Single Cotton, 4-Mils | Double Cotton, 8-Mils | Single Silk, 1¼-Mils | Double Silk, 4-Mils | Enamel |
|----------------------------|-----------------------------|-----------------------------|----------------------------|---------------------------|--------|
| 20 | 311 | 298 | 319 | 312 | 320 |
| 21 | 389 | 370 | 403 | 389 | 404 |
| 22 | 488 | 461 | 503 | 493 | 509 |
| 23 | 612 | 584 | 636 | 631 | 642 |
| 24 | 762 | 745 | 800 | 779 | 810 |
| 25 | 957 | 903 | 1,005 | 966 | 1,019 |
| 26 | 1,192 | 1,118 | 1,265 | 1,202 | 1,286 |
| 27 | 1,488 | 1,422 | 1,590 | 1,543 | 1,620 |
| 28 | 1,852 | 1,759 | 1,972 | 1,917 | 2,042 |
| 29 | 2,375 | 2,207 | 2,500 | 2,485 | 2,570 |
| 30 | 2,860 | 2,534 | 3,145 | 2,909 | 3,240 |
| 31 | 3,500 | 2,768 | 3,943 | 3,683 | 4,082 |
| 32 | 4,375 | 3,737 | 4,950 | 4,654 | 5,132 |
| 33 | 5,390 | 4,697 | 6,180 | 5,689 | 6,445 |
| 34 | 6,500 | 6,168 | 7,740 | 7,111 | 8,093 |
| 35 | 8,050 | 6,737 | 9,600 | 8,534 | 10,197 |
| 36 | 9,820 | 7,877 | 12,000 | 10,039 | 12,813 |
| 37 | 11,860 | 9,309 | 15,000 | 11,666 | 16,110 |
| 38 | 14,300 | 10,636 | 18,660 | 14,222 | 20,274 |
| 39 | 17,130 | 11,907 | 23,150 | 16,516 | 25,519 |
| 40 | 21,590 | 14,222 | 28,700 | 21,333 | 32,107 |

CHARACTERISTICS OF RECEIVING VACUUM TUBES

| Type | Filament | | Type of "A." Supply | Grid leak Megohms | Plate Voltage | | Amplifier Grid Bias Volts | Voltage Amplification Factor | Output | | | Use |
|----------------|------------------|---------|---------------------|-------------------|---------------|-----------|------------------------------------|------------------------------|-----------------|-------------------------|--------------|-----------------------|
| | Terminal Voltage | Current | | | Detector | Amplifier | | | Milliwatts Max. | Current D.C. Milliamps. | Voltage D.C. | |
| WD-11 WX-12 | 1.1 | 0.25 | Dry cells | 3-5 | 22½-45 | 90-135 | 4½-10½ | 6.6 | 7-35 | | | Detector or Amplifier |
| UX-112-A | 5.0 | 0.25 | Storage battery | 3-5 | 45 | 90-135 | 4½-9 | 8.0 | 30-120 | | | Detector or Amplifier |
| UY-199 | 3.0 | 0.060 | Dry cells | 2-9 | 45 | 90 | 4½ | 6.6 | 7 | | | Detector or Amplifier |
| UX-199 | 3.3 | 0.063 | Dry cells | | | | | | | | | Detector |
| UX-200-A | 5.0 | 0.25 | Storage battery | 2-3 | 45 | — | — | 20 | — | | | Detector |
| UX-201-A | 5.0 | 0.25 | Storage battery | 2-9 | 45 | 90-135 | 4½-9 | 8.0 | 15-55 | | | Detector or Amplifier |
| UX-222 | 3.3 | 0.132 | Storage battery | — | — | 135 | Inner grid - 1½ Outer grid + 45 | 300.0 | — | | | R-f. Amplifier |
| | | | Storage battery | | | 180 | Outer grid - 1½ | 66.0 | — | | | A-f. Amplifier |
| | | | Storage battery | | | 180 | Inner grid + 22½ | 60.0 | — | | | Detector |
| UY-224 | 2.5 A.C. | 1.75 | Transformer | | | | Inner grid - 1½ Outer grid + 75 | | — | | | Detector or Amplifier |

| | | | | | | | | | | |
|----------|----------|-----------|-----------------|------------|----------------|------------------|------------------|------|----------|-----------------------|
| UX-226 | 1.5 A.C. | 1.05 | Transformer | — | — | 90-180 | 6-13½ | 8.2 | 20-160 | Amplifier |
| UY-227 | 2.5 A.C. | 1.75 | Transformer | 2-9 | 45 | 180 | | 8.0 | — | Detector |
| UX-240 | 5.0 | 0.25 | Storage battery | ¼-1 2-5 | 90 135-180 | 135-180 | 1½-3 | 30.0 | — | Detector or Amplifier |
| UX-112-A | 5.0 | 0.25 | Storage battery | — | — | 135-157½ | 9-10½ | 8.0 | 120-195 | Power Amplifier |
| UX-120 | 3.0 3.3 | .125-.132 | Dry cells | — | — | 135 | 22½ | 3.3 | 110 | Power Amplifier |
| UX-171-A | 5.0 | 0.25 | Storage battery | — | — | 90 135 180 | 16½ 27 40½ | 3.0 | 130-700 | Power Amplifier |
| UX-210 | 7.5 | 1.25 | Transformer | — | — | 250-425 | 18-35 | 8.0 | 340-1540 | Power Amplifier |
| UX-245 | 2.5 | 1.5 | Transformer | — | — | 180-250 | 33-50 | 3.5 | 1600 | Power Amplifier |
| UX-250 | 7.5 | 1.25 | Transformer | — | — | 450 | 84 | 3.8 | 4050 | Power Amplifier |
| UX-213 | 5.0 A.C. | 2.0 | Transformer | Max. A.C. | Plate Voltage- | | — | — | — | 65 170 |
| UX-216-B | 7.5 A.C. | 1.25 | Transformer | 220 | | | — | — | — | 65 470 |
| UX-280 | 5.0 A.C. | 2.0 | Transformer | Max. A.C. | Plate Voltage- | | — | — | — | 125 260 |
| UX-281 | 7.5 A.C. | 1.25 | Transformer | 550 | | | — | — | — | 65-110 620 |
| | | | | 300 | | | | | | |
| | | | | Max. A.C. | Plate Voltage- | | | | | |
| | | | | 750 | | | | | | |

INTERNATIONAL MORSE, CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots. 3. The space between two letters is equal to three dots.
2. The space between parts of the same letter is equal to one dot. 4. The space between two words is equal to five dots.

| | |
|-------------------------------|--|
| A | Period |
| B | Semicolon |
| C | Comma |
| D | Colon |
| E | Interrogation |
| F | Exclamation point |
| G | Apostrophe |
| H | Hyphen |
| I | Bar indicating fraction |
| J | Parenthesis |
| K | Inverted commas |
| L | Underline |
| M | Double dash |
| N | Distress Call |
| O | Attention call to precede every transmission |
| P | General inquiry call |
| Q | From (de) |
| R | Invitation to transmit (go ahead) |
| S | Warning—high power |
| T | Question (please repeat after)—interrupting long messages. |
| U | Wait |
| V | Break (Bk.) (double dash) |
| W | Understand |
| X | Error |
| Y | Received (O. K.) |
| Z | Position report (to precede all position messages) |
| Ä (German) | End of each message (cross) |
| Á or Ā (Spanish-Scandinavian) | Transmission finished (end of work) (conclusion of correspondence) |
| CH (German-Spanish) | |
| É (French) | |
| Ñ (Spanish) | |
| Ü (German) | |
| U (German) | |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 0 | |













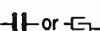




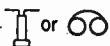





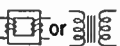














ABBREVIATIONS USED IN RADIO COMMUNICATION INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

| Abbreviation | Question | Answer or Notice |
|--------------|---|--|
| PRD | Do you wish to communicate by means of the International Signal Code? | I wish to communicate by means of the International Signal Code. |
| QRA | What ship or coast station is that? | This is..... |
| QRB | What is your distance?..... | My distance is..... |
| QRC | What is your true bearing?..... | My true bearing is.....degrees. |
| QRD | Where are you bound for?..... | I am bound for..... |
| QRF | Where are you bound from?..... | I am bound from..... |
| QRC | What line do you belong to?..... | I belong to the.....Line. |
| QRH | What is your wavelength in meters? | My wavelength is.....meters. |
| QRI | How many words have you to send? | I have.....words to send. |
| QRK | How do you receive me? | I am receiving well. |
| QRL | Are you receiving badly? Shall I send 20?..... | I am receiving badly. Please send 20. |
| | • • • — • | • • • — • |
| | for adjustment? | for adjustment. |
| QRM | Are you being interfered with?..... | I am being interfered with. |
| QRN | Are the atmospherics strong?..... | Atmospherics are very strong. |
| QRO | Shall I increase power?..... | Increase power. |
| QRP | Shall I decrease power?..... | Decrease power. |
| QRQ | Shall I send faster?..... | Send faster. |
| QRS | Shall I send slower?..... | Send slower. |
| QRT | Shall I stop sending?..... | Stop sending. |
| QRU | Have you anything for me?..... | I have nothing for you. |
| QRV | Are you ready?..... | I am ready. All right now. |
| QRW | Are you busy?..... | I am busy (or: I am busy with....). Please do not interfere. |
| QRX | Shall I stand by?..... | Stand by. I will call you when required. |
| QRY | When will be my turn?..... | Your turn will be No..... |
| QRZ | Are my signals weak?..... | Your signals are weak. |
| QSA | Are my signals strong?..... | Your signals are strong. |
| QSB | Is my tone bad?..... | The tone is bad. |
| | Is my spark bad?..... | The spark is bad. |
| QSC | Is my spacing bad?..... | Your spacing is bad. |
| QSD | What is your time?..... | My time is..... |
| QSF | Is transmission to be in alternate order or in series? | Transmission will be in alternate order. |
| QSG | ..... | Transmission will be in series of 5 messages. |
| QSH | ..... | Transmission will be in series of 10 messages. |
| QSJ | What rate shall I collect for..... | Collect..... |
| QSK | Is the last radiogram canceled?..... | The last radiogram is canceled. |
| QSL | Did you get my receipt?..... | Please acknowledge. |
| QSM | What is your true course?..... | My true course is.....degrees. |
| QSN | Are you in communication with land?..... | I am not in communication with land. |
| QSO | Are you in communication with any ship or station (or: with.....)? | I am in communication with..... (through.....) |
| QSP | Shall I inform.....that you are calling him? | Inform.....that I am calling him. |
| QSQ | Is.....calling me?..... | You are being called by..... |
| QSR | Will you forward the radiogram?..... | I will forward the radiogram. |
| QST | Have you received the general call? | General call to all stations. |
| QSU | Please call me when you have finished (or: at.....o'clock)? | Will call when I have finished. |
| *QSV | Is public correspondence being handled?..... | Public correspondence is being handled. Please do not interfere. |
| QSW | Shall I increase my spark frequency? | Increase your spark frequency. |
| QSX | Shall I decrease my spark frequency? | Decrease your spark frequency. |
| QSY | Shall I send on a wavelength of.....meters? | Let us change to the wavelength of.....meters. |
| QSZ | ..... | Send each word twice. I have difficulty in receiving you. |
| QTA | ..... | Repeat the last radiogram. |

* Public correspondence is any radio work, official or private, handled on commercial wavelengths.

When an abbreviation is followed by a mark of interrogation, it refers to the question indicated for that abbreviation.

SYMBOLS USED FOR APPARATUS

| | | | |
|--------------------------|---|------------------------|---|
| Alternator..... |  | Key..... |  |
| Ammeter..... |  | Resistor..... |  |
| Aerial..... |  | Variable Resistor..... |  |
| Arc..... |  | Switch s.p.s.t..... |  |
| Battery..... |  | Switch s.p.d.t..... |  |
| Buzzer..... |  | Switch d.p.s.t..... |  |
| Condenser..... |  | Switch d.p.d.t..... |  |
| Variable Condenser..... |  | Switch Reversing..... |  |
| Connection of Wires..... |  | Phone Receiver..... |  |
| No Connection..... |  | Phone Transmitter..... |  |
| Coupled Coils..... |  | Thermoelement..... |  |
| Variable Coupling..... |  | Transformer..... |  |
| Detector, Crystal..... |  | Vacuum Tube..... |  |
| Gap, Plain..... |  | Screen Grid Tube..... |  |
| Gap, Quenched..... |  | Heater Type Tube..... |  |
| Ground..... |  | Voltmeter..... |  |
| Hot Wire Ammeter..... |  | Choke Coil..... |  |
| Inductor..... |  | Loop Aerial..... |  |
| Variable Inductor..... |  | Telephone Jack..... |  |

DEFINITIONS OF ELECTRIC AND MAGNETIC
UNITS

The *ohm* is the resistance of a thread of mercury at the temperature of melting ice, 14.4521 grams in mass, of uniform cross-section and a length of 106.300 centimeters.

The *ampere* is the current which when passed through a solution of nitrate of silver in water according to certain specifications, deposits silver at the rate of 0.00111800 of a gram per second.

The *volt* is the electromotive force which produces a current of 1 ampere when steadily applied to a conductor the resistance of which is 1 ohm.

The *coulomb* is the quantity of electricity transferred by a current of 1 ampere in 1 second.

The *ampere-hour* is the quantity of electricity transferred by a current of 1 ampere in 1 hour and is, therefore, equal to 3600 coulombs.

The *farad* is the capacity of a condenser in which a potential difference of 1 volt causes it to have a charge of 1 coulomb of electricity.

The *henry* is the inductance in a circuit in which the electromotive force induced is 1 volt when the inducing current varies at the rate of 1 ampere per second.

The *watt* is the power spent by a current of 1 ampere in a resistance of 1 ohm.

The *joule* is the energy spent in 1 second by a flow of 1 ampere in 1 ohm.

The *horsepower* is used in rating steam machinery. It is equal to 746 watts.

The *kilowatt* is 1,000 watts.

The units of capacity actually used in radio work are the *microfarad*, which is the millionth part of a farad, because the farad is too large a unit; and the *c.g.s. electrostatic unit of capacity*, which is often called the *centimeter of capacity*, which is about equal to 1.11 microfarads.

The units of inductance commonly used in radio work are the *millihenry*, which is the thousandth part of a henry; and

the *centimeter of inductance*, which is one one-thousandth part of a microhenry.

Note.—For further information about electric and magnetic units get the *Bureau of Standards Circular No. 60*, called *Electric Units and Standards*, the price of which is 15 cents; also get *Scientific Paper No. 292*, called *International System of Electric and Magnetic Units*, price 10 cents. These and other informative papers can be had from the *Superintendent of Documents, Government Printing Office, Washington, D. C.*

SELECTED BOOKS ON RADIO AND TELEVISION

- The Admiralty Manual of Wireless Telegraphy.* 1920. Published by His Majesty's Stationery Office, London.
- Stuart Ballantine.—*Radio Telephony for Amateurs.* 2 ed. 1923. David McKay Co., Phila., Pa.
- A. Frederick Collins.—*Wireless Telegraphy, Its History, Theory, and Practice.* 1905. McGraw Pub. Co., New York City.
- A. Frederick Collins.—*Experimental Television.* 1932. Lothrop, Lee, & Shepard Co., Boston, Mass.
- J. H. Dellinger.—*Principles Underlying Radio Communication.* 1921. Signal Corps, U. S. Army, Washington, D. C.
- H. M. Dorsett.—*Wireless Telegraphy and Telephony.* 1920. Wireless Press, Ltd., London.
- Duncan and Drew.—*Radio Telegraphy and Telephony.* 1929. John Wiley & Sons, New York City.
- Edgar H. Felix.—*Television; Its Methods and Uses.* 1931. McGraw-Hill Book Co., Inc., New York City.
- J. A. Fleming.—*Principles of Electric Wave Telegraphy.* 1919. Longmans, Green and Co., London.
- Charles B. Hayward.—*How to Become a Wireless Operator.* 1918. *Modern Radio Practice*, Revised Edition. 1923. American Technical Society, Chicago, Ill.
- John V. L. Hogan.—*The Outline of Radio.* 1928. Revised Edition. Little, Brown, and Co., Boston, Mass.
- R. R. Ramsey.—*Fundamentals of Radio.* 1929. Published by the author at Indiana University.

- C. Francis Jenkins.—*Radiomovies, Radiovision, Television*. 1929. Jenkins Laboratories, Washington, D. C.
- Ladner and Stoner.—*Short Wave Wireless Communication*. 1933. John Wiley & Sons, New York City.
- John H. Morecroft.—*Elements of Radio Communication*. 1929. John Wiley & Sons, New York City.
- Moseley and Chapple.—*Television, To-Day and To-Morrow*. 1931. Sir Isaac Pitman and Sons, Ltd., New York City.
- Moyer and Wostrel.—*Radio Handbook*. 1931. McGraw-Hill Book Co., Inc., New York City.
- Nilson and Hornung.—*Radio Operating Questions and Answers*. 1932. McGraw-Hill Book Co., Inc., New York City.
- S. S. Robison.—*Manual of Radio Telegraphy and Telephony*. 1920. Revised Edition, 1927. United States Naval Institute, Annapolis, Md.
- James L. Thomas.—*Fundamentals of Radio*. 1923. D. Van Nostrand Company, New York City.
- L. B. Turner.—*Wireless Telegraphy and Telephony*. 1921. Cambridge University Press. Cambridge, England.
- J. A. W. Zenneck.—*Wireless Telegraphy*. 1915. McGraw-Hill Book Company, New York City.

Send to the *Superintendent of Documents, Government Printing Office, Washington, D. C.*, for special lists on radio, and for a copy of *Price List No. 64* which lists the Government's books and pamphlets on radio. These will be sent to you free of charge.

**MANUFACTURERS AND DEALERS IN
APPARATUS AND SUPPLIES**

- Allen-Bradley Co., Milwaukee, Wis.
American Hard Rubber Co., 11 Mercer Street, New York City.
Atwater-Kent Mfg. Co., Philadelphia, Pa.
Bunnell (J. H.) & Co., 215 Fulton St., New York City.
Burgess Battery Company, Harris Trust Co. Bldg., Chicago, Ill.
Connecticut Telephone and Electric Corp., Meriden, Conn.
Crosley Mfg. Co., Cincinnati, Ohio.
Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Dubilier Condenser Corp., 4377 Bronx Blvd., New York City.
Edison Storage Battery Co., Orange, N. J.
Electrad, Inc., 175 Varick St., New York, N. Y.
Electric Specialty Co., Stamford, Conn.
Electric Storage Battery Co., Philadelphia, Pa.
Fansteel Products Co., Inc., North Chicago, Ill.
General Electric Co., Schenectady, N. Y.
Hammarlund Mfg. Co., 424 W. 33 St., New York City.
International Brass and Electric Co., 76 Beekman St., New
York City.
Jenkins Television Corp., Manhattan Ave., Passaic, N. J.
Lincoln Radio Corp., 329 S. Wood St., Chicago, Ill.
Manhattan Electrical Supply Co., Inc., 100 6th Ave., New
York City.
National Carbon Co., Inc., 30 E. 42nd St., New York City.
The National Company, Malden, Mass.
Pacent Electric Co., 91 7th Ave., New York City.
Pilot Radio & Tube Corp., Lawrence, Mass.
RCA Radiotron Co., Harrison, N. J.
Radio Corporation of America, 570 Lexington Ave., New York
City.
Radio Engineering Laboratories, 25-14, 41st Ave., Long Island
City, N. Y.
Roller-Smith Co., 233 Broadway, New York City.
E. H. Scott Radio Laboratories, Inc., 4450 Ravenswood Ave.,
Chicago, Ill.
Western Electric Co., Chicago, Ill.

Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.
Weston Electrical Instrument Co., 614 Frelinghuysen Ave.,
Newark, N. J.

RADIO MAGAZINES

In an industry that makes such rapid progress as radio it is rather essential that those interested in the art subscribe to one or two magazines in order that they may keep up with the latest developments. Below will be found the names of some magazines devoted to radio in its different phases:

RADIO, 449 Pacific Bldg., San Francisco, Calif.—Deals with latest developments in manufactured sets, constructional articles, amateur developments.

QST, Hartford, Conn.—Strictly an amateur's magazine; deals with their problems and is the official organ of the A. R. R. L.

RADIO NEWS, 222 West 39th St., New York, N. Y.—General radio articles; constructional articles; deals with the application of radio principles to other sciences.

RADIO-CRAFT, 96 Park Place, New York, N. Y.—Similar to *Radio News*.

RADIO ENGINEERING, 19 East 47th St., New York, N. Y.—A technical, industrial magazine, dealing with the latest engineering developments in radio and allied fields.

RADIO WORLD, 145 W. 45th St., New York, N. Y.—Constructional articles, general articles, broadcast station news, etc.

SHORT WAVE CRAFT, 96 Park Place, New York City.—A monthly magazine dealing with reception and transmission under 200 meters. General articles; constructional details for transmitters and receivers; information on short-wave and television broadcast stations throughout the world.

RADIO REVIEW AND TELEVISION NEWS, 96 Park Place, New York City.—Bi-monthly. A review of foreign receiving and transmitting circuits adapted to American apparatus; television constructional and general articles.

ABBREVIATIONS OF COMMON TERMS

| | | |
|-----------|-------|--------------------------------------|
| A. | ..... | Aerial |
| A.C. | ..... | Alternating Current |
| A.F. | ..... | Audio-Frequency |
| B. and S. | ..... | Brown & Sharpe Wire Gauge |
| C. | ..... | Capacity or Capacitance |
| C.G.S. | ..... | Centimeter-Gram-Second |
| Cond. | ..... | Condenser |
| Coup. | ..... | Coupler |
| C.W. | ..... | Continuous Waves |
| D.C. | ..... | Direct Current |
| D.P.D.T. | ..... | Double Point Double Throw |
| D.P.S.T. | ..... | Double Point Single Throw |
| D.X. | ..... | Distance |
| E. | ..... | Short for Electromotive Force (Volt) |
| E.M.F. | ..... | Electromotive Force |
| F. | ..... | Filament or Frequency |
| G. | ..... | Grid |
| Gnd. | ..... | Ground |
| I. | ..... | Current Strength (Ampere) |
| I.C.W. | ..... | Interrupted Continuous Waves |
| I.F. | ..... | Intermediate Frequency |
| KW. | ..... | Kilowatt |
| L. | ..... | Inductance |
| L.C. | ..... | Loose Coupler |
| Litz. | ..... | Litzendraht |
| Mfd. | ..... | Microfarad |
| Neg. | ..... | Negative |
| O.T. | ..... | Oscillation Transformer |
| P. | ..... | Plate |
| P.A. | ..... | Public Address System |
| Prim. | ..... | Primary |
| Pos. | ..... | Positive |
| R. | ..... | Resistance |
| R.F. | ..... | Radio-Frequency |
| Sec. | ..... | Secondary |
| S.L.F. | ..... | Straight Line Frequency |

| | |
|----------------|--|
| S.P.D.T..... | Single Point Double Throw |
| S.P.S.T..... | Single Point Single Throw |
| S.R..... | Self-Rectifying |
| T..... | Telephone or Period (time) of Complete Oscillation |
| Tick..... | Tickler |
| V..... | Potential Difference |
| Var. Cond..... | Variable Condenser |
| V.T..... | Vacuum Tube |
| W.L..... | Wavelength |
| X..... | Reactance |
| Z..... | Impedance |

GLOSSARY

A BATTERY.—See *Battery A*.

ABBREVIATIONS, CODE.—Abbreviations of questions and answers used in wireless communication. The abbreviation of a question is usually in three letters of which the first is *Q*. Thus *Q R B* is the code abbreviation of “*what is your distance?*” and the answer “*my distance is . . .*”

ABBREVIATIONS, UNITS.—Abbreviations of various units used in radio electricity. These abbreviations are usually lower case letters of the Roman alphabet, but occasionally Greek letters are used and other signs. Thus *amperes* is abbreviated *amp.*, *micro*, which means *one millionth*, μ , etc.

ABBREVIATIONS OF WORDS AND TERMS.—Letters used instead of words and terms for shortening them up where there is a constant repetition of them, as *A.C.* for *alternating current*; *C.W.* for *continuous waves*; *V.T.* for *vacuum tube*, etc. See page 272.

AERIAL.—Also called *antenna*. An aerial wire. One or more wires suspended in the air and insulated from its supports. It is the aerial that sends out the waves and receives them.

AERIAL, AMATEUR.—An aerial suitable for sending out 200 meter wavelengths or less. Such an aerial wire system must not exceed 120 feet in length from the ground up to the aerial switch and from this through the lead-in wire to the end of the aerial.

AERIAL AMMETER.—See *Ammeter, Hot-Wire*.

AERIAL, INDOOR.—Where an outdoor aerial is not practicable a wire strung around a room is often made to serve the purpose.

AERIAL CAPACITY.—See *Capacity, Aerial*.

AERIAL COUNTERPOISE.—Where it is not possible to get a good ground an *aerial counterpoise* or *earth capacity* can be used

- to advantage. The counterpoise is made like the aerial and is supported directly under it close to the ground but insulated from it.
- AERIAL, DIRECTIONAL.**—An inverted L or other aerial that will transmit and receive over greater distances to and from one direction than to and from another.
- AERIAL, GROUND.**—Signals can be received on a single long wire when it is placed on or buried in the earth or immersed in water. It is also called a *ground antenna* and an *underground aerial*.
- AERIAL, LOOP.**—Also called a *coil aerial*, *coil antenna*, *loop aerial*, *loop antenna* and when used for the purpose a *direction finder*. A coil of wire wound on a vertical frame.
- AERIAL RESISTANCE.**—See *Resistance, Aerial*.
- AERIAL SWITCH.**—See *Switch, Aerial*.
- AERIAL WIRE.**—(1) A wire or wires that form the aerial. (2) Wire that is used for aeriels; this is usually copper or copper alloy.
- AERIAL WIRE SYSTEM.**—An aerial and ground wire and that part of the inductance coil which connects them. The open oscillation circuit of a sending or a receiving station.
- AIR CORE TRANSFORMER.**—See *Transformer, Air Core*.
- ALTERNATOR.**—An electric machine that generates alternating current.
- ALPHABET, INTERNATIONAL CODE.**—A modified Morse alphabet of dots and dashes originally used in Continental Europe and, hence, called the *Continental Code*. It is now used for all general public service radio communication all over the world and, hence, it is called the *International Code*. See page 278.
- ALTERNATING CURRENT (A.C.).**—See *Current*.
- ALTERNATING CURRENT TRANSFORMER.**—See *Transformer*.
- AMATEUR AERIAL OR ANTENNA.**—See *Aerial, Amateur*.
- AMATEUR GROUND.**—See *Ground, Amateur*.
- AMMETER.**—An instrument used for measuring the current strength, in terms of amperes, that flows in a circuit. Ammeters used for measuring direct and alternating currents make use of the *magnetic effects* of the currents. High-fre-

quency currents as measured by the *heating effects* of the currents.

AMMETER, AERIAL.—See *Ammeter, Hot-Wire*.

AMMETER, HOT-WIRE.—High-frequency currents are usually measured by means of an instrument which depends on heating a wire or metal strip by the oscillations. Such an instrument is often called a *thermal ammeter, radio ammeter* and *aerial ammeter*.

AMMETER, RADIO.—See *Ammeter, Hot-Wire*.

AMPERE.—The current which when passed through a solution of nitrate of silver in water according to certain specifications, deposits silver at the rate of 0.00111800 of a gram per second.

AMPERE-HOUR.—The quantity of electricity transferred by a current of 1 ampere in 1 hour and is, therefore, equal to 3600 coulombs.

AMPERE-TURNS.—When a coil is wound up with a number of turns of wire and a current is made to flow through it, it behaves like a magnet. The strength of the magnetic field inside of the coil depends on (1) the strength of the current and (2) the number of turns of wire on the coil. Thus a feeble current flowing through a large number of turns will produce as strong a magnetic field as a strong current flowing through a few turns of wire. This product of the current in amperes times the number of turns of wire on the coil is called the *ampere-turns*.

AMPLIFICATION, AUDIO-FREQUENCY.—A current of audio-frequency that is amplified by an amplifier tube or other means.

AMPLIFICATION, CASCADE.—See *Cascade Amplification*.

AMPLIFICATION, RADIO-FREQUENCY.—A current of radio-frequency that is amplified by an amplifier tube or other means before it reaches the detector.

AMPLIFICATION, REGENERATIVE.—A scheme that uses a third circuit to feed back part of the oscillations through a vacuum tube and which increases its sensitiveness when used as a detector and multiplies its action as an amplifier.

AMPLIFIER, AUDIO-FREQUENCY.—A vacuum tube or other device that amplifies the signals after passing through the detector.

- AMPLIFIER, MAGNETIC.**—A device used for controlling radio-frequency currents either by means of a telegraph key or a microphone transmitter. The controlling current flows through a separate circuit from that of the radio current and a fraction of an ampere will control several amperes in the aerial wire.
- AMPLIFIER, MULTI-STAGE.**—A receiving set using two or more amplifiers. Also called *cascade amplification*. Two or more vacuum tubes with suitable coupling devices to magnify minute currents.
- AMPLIFIER, VACUUM TUBE.**—A vacuum tube that is used either to amplify the radio-frequency currents or the audio-frequency currents.
- AMPLIFYING TRANSFORMER, AUDIO.**—See *Transformer, Audio Amplifying*.
- AMPLIFYING MODULATOR VACUUM TUBE.**—See *Vacuum Tube, Amplifying Modulator*.
- AMPLIFYING TRANSFORMER RADIO.**—See *Transformer, Radio Amplifying*.
- AMPLITUDE OF WAVE.**—The distance of the crest from the 0 line.
- ANODE**—(1) An electrode towards which electrons flow in a tube.
(2) A positively charged electrode. See *Cathode*.
- ANTENNA, AMATEUR.**—See *Aerial, Amateur*.
- ANTENNA SWITCH.**—See *Switch, Aerial*.
- APERIODIC CIRCUIT.**—One which has no natural period of oscillation; an untuned circuit.
- APPARATUS SYMBOLS.**—See *Symbols, Apparatus*.
- ARMSTRONG CIRCUIT.**—See *Circuit, Armstrong*.
- ATMOSPHERICS.**—Same as *Static*, which see.
- ATTENUATION.**—In sending radio telegraph and telephone messages the energy of the electric waves decreases as the distance increases. This is called *attenuation* and it varies with the seasons of the year; night and day, etc.
- AUDIBILITY METER.**—See *Meter, Audibility*.
- AUDIO-FREQUENCY.**—See *Frequency, Audio*.
- AUDIO-FREQUENCY AMPLIFICATION.**—See *Amplification, Audio-Frequency*.

AUDIO-FREQUENCY AMPLIFIER.—See *Amplifier, Audio-Frequency*.

AUDIO-FREQUENCY CURRENT.—See *Current, Audio-Frequency*.

AUDION.—An early trade name given to the vacuum tube detector.

AUTODYNE RECEIVER.—See *Receiver, Autodyne*.

AUTO-TRANSFORMER.—See *Transformer, Auto*.

BAKELITE.—A manufactured insulating compound.

B BATTERY.—See *Battery B*.

BAND, WAVELENGTH.—See *Wavelength Band*.

BASKET WOUND COILS.—See *Coils, Inductance*.

BATTERY, A.—The battery used to heat the filament of a vacuum tube.

BATTERY, B.—The battery used to energize the plate of a vacuum tube.

BATTERY, BOOSTER.—This is the battery that is connected in series with the crystal detector.

BATTERY, C.—A small battery used to give the grid of a vacuum tube an extra negative, or bias, potential.

BATTERY, EDISON STORAGE.—A storage battery in which the elements are made of nickel and iron and immersed in an alkaline *electrolyte*.

BATTERY, LEAD STORAGE.—A storage battery in which the elements are made of lead and immersed in an acid *electrolyte*.

BATTERY POLES.—See *Poles, Battery*.

BATTERY, PRIMARY.—A battery that generates current by chemical action.

BATTERY, STORAGE.—A battery that develops a current after it has been charged.

BEAT RECEPTION.—See *Heterodyne Reception*.

BLUB BLUB.—Over modulation in wireless telephony.

BLUE GLOW DISCHARGE.—See *DISCHARGE*.

BOOSTER BATTERY.—See *Battery, Booster*.

BROADCASTING.—Sending out intelligence and music from a central station for the benefit of all who live within range of it and who have receiving sets.

BROAD WAVE.—See *Wave, Broad*.

BRUSH DISCHARGE.—See *Discharge*.

BUZZER MODULATION.—See *Modulation, Buzzer*.

CAPACITIVE COUPLING.—See *Coupling, Capacitive*.

CAPACITY.—The capacity of a condenser, inductance coil or other device capable of retaining a charge of electricity, hence an aerial wire, a condenser or a metal plate is sometimes called a *capacity*. Capacity is measured in terms of the *farad*.

CAPACITY, AERIAL.—The capacity between the aerial wires and the ground or the counterpoise. The *capacity* of a small amateur aerial is from 0.0002 to 0.0005 microfarad.

CAPACITY, DISTRIBUTED.—A coil of wire not only has inductance, but also a certain small capacity. Coils wound with their turns parallel and having a number of layers have a *bunched capacity* which produces untoward effects in oscillation circuits. In honeycomb and other stagger wound coils the capacity is more evenly distributed.

CAPACITY REACTANCE.—See *Reactance, Capacity*.

CAPACITY UNIT.—See *Farad*.

CARBON RHEOSTATS.—See *Rheostat, Carbon*.

CARBORUNDUM DETECTOR.—See *Detector*.

CARRIER CURRENT TELEPHONY.—See *Wired-Wireless*.

CARRIER FREQUENCY.—See *Frequency, Carrier*.

CARRIER FREQUENCY TELEPHONY.—See *Wired-Wireless*.

CASCADE AMPLIFICATION.—Two or more amplifying tubes in a receiver having some type of coupling device between them.

CATHODE.—(1) An electrode from which electrons flow in a tube. (2) A negatively charged electrode. See *Anode*.

CAT WHISKER CONTACT.—A long, thin wire which makes contact with the crystal of a detector.

CELLULAR COILS.—See *Coils, Inductance*.

CENTIMETER OF CAPACITY.—Equal to 1.11 *microfarads*.

CENTIMETER OF INDUCTANCE.—Equal to one one-thousandth part of a *microhenry*.

C.G.S. ELECTROSTATIC UNIT OF CAPACITY.—See *Centimeter of Capacity*.

CHANNEL.—A narrow band of radio wavelengths.

CHARACTERISTICS.—The special behavior of a device, such as an aerial, a detector tube, etc.

CHARACTERISTICS, GRID.—See *Grid Characteristics*.

CHOKER COILS R-F.—Coils that prevent the high-voltage oscillations from surging back into the transformer and getting into the a-f. circuits.

CHOPPER MODULATION.—See *Modulation, Chopper*.

CIRCUIT.—Any electrical conductor through which a current can flow. A low-voltage current requires a loop of wire or other conductor both ends of which are connected to the source of current before it can flow. A high-frequency current will surge in a wire which is open at both ends like the aerial.

Closed Circuit.—A circuit that is continuous.

Open Circuit.—A conductor that is not continuous.

Coupled Circuits.—Open and closed circuits connected together by inductance coils, condensers or resistances. See *coupling*.

Close Coupled Circuits.—Open and closed circuits connected directly together with a single inductance coil.

Loose Coupled Circuits.—Opened and closed circuits connected together inductively by means of a transformer.

Stand-by Circuits.—Also called *pick-up* circuits. When listening-in for possible calls from a number of stations, a receiver is used which will respond to a wide band of wavelengths.

Armstrong Circuit.—The regenerative circuit invented by Major E. H. Armstrong.

CLOSED CIRCUIT.—See *Circuit, Closed*.

CLOSED CORE TRANSFORMER.—See *Transformer, Closed Core*.

CLOSE COUPLED CIRCUITS.—See *Circuits, Close Coupled*.

CODE.—

Continental.—Same as *International*.

International.—On the continent of Europe land lines use the *Continental Morse* alphabetic code. This code has come to be used throughout the world for wireless telegraphy and hence it is now called the *International code*. It is given on page 272.

Morse.—The code devised by Samuel F. B. Morse and which is used on the land lines in the U. S.

National Electric.—A set of rules and requirements devised by the *National Board of Fire Underwriters* for the electrical installations in buildings on which insurance companies carry risks. This code also covers the requirements for wireless installations. A copy may be had from the *National Board of Fire Underwriters*, New York City, or from your insurance agent.

National Electric Safety.—The *Bureau of Standards*, Washington, D. C., have investigated the precautions which should be taken for the safe operation of all electric equipment. A copy of the *Bureau of Standards Handbook No. 3* can be had for 40 cents from the *Superintendent of Documents*.

COEFFICIENT OF COUPLING.—See *Coupling, Coefficient of*.

COIL AERIAL.—See *Aerial, Loop*.

COIL ANTENNA.—See *Aerial, Loop*.

COIL, INDUCTION.—An apparatus for changing low-voltage direct currents into high-voltage, low-frequency alternating currents. When fitted with a spark gap the high-voltage, low-frequency currents are converted into high-voltage, high-frequency currents. It is then also called a *spark coil* and a *Ruhmkorff coil*.

COIL, LOADING.—A coil connected in the aerial or closed oscillation circuit so that longer wavelengths can be received.

COIL, REPEATING.—See *Repeating Coil*.

COIL, ROTATING.—One which rotates on a shaft instead of sliding as in a *loose coupler*. The *rotor* of a *variometer* or *variocoupler* is a *rotating coil*.

COILS, INDUCTANCE.—These are the tuning coils used in sending and receiving sets. For transmitters they are formed of one and two coils, a single sending coil is generally called a *tuning inductance coil*, while a two-coil tuner is called an *oscillation transformer*. Receiving tuning coils are made with a single layer, single coil, or a pair of coils, when it is called an *oscillation transformer*. A *loose-coupler* tuning coil is formed of two coils inductively connected; it is a receiving

oscillation transformer. Some tuning inductance coils have more than one layer; they are then called *lattice wound*, *cellular*, *basket wound*, *honeycomb*, *duo-lateral*, *stagger wound*, *spider-web* and *slab* coils.

COMMERCIAL FREQUENCY.—See *Frequency, Commercial*.

CONDENSER.—All conducting objects with their insulation form capacities, but a *condenser* is understood to mean two sheets or plates of metal placed closely together but separated by some insulating material.

Adjustable Condenser.—Where two or more condensers can be coupled together by means of plugs, switches or other devices.

Aerial Condenser.—A condenser connected in the aerial.

Air Condenser.—Where air only separates the sheets of metal.

By-Pass Condenser.—A condenser connected in a circuit so that the high-frequency currents will have an alternative path to flow through.

Filter Condenser.—A condenser of large capacity used in combination with a filter reactor for smoothing out the pulsating direct currents as they come from the rectifier.

Fixed Condenser.—Where the plates are fixed relatively to one another.

Grid Condenser.—A condenser connected in series with the grid lead.

Leyden Jar Condenser.—Where glass jars are used.

Mica Condenser.—Where mica is used as a dielectric.

Oil Condenser.—Where the plates are immersed in oil.

Paper Condenser.—Where paper is used as the insulating material.

Protective.—A condenser of large capacity connected across the low-voltage supply circuit of a transmitter to form a by-path of kick-back oscillations.

Variable Condenser.—Where alternate plates can be moved and so made to interleave more or less with a set of fixed plates.

Vernier.—A small condenser with a vernier on it so that it may be accurately varied. It is connected in parallel

- with the variable condenser used in the primary circuit and is used for the reception of continuous waves where sharp tuning is essential. A small variable condenser used for receiving continuous waves where very sharp tuning is desired.
- CONDENSER, AERIAL SERIES.—A condenser placed in the aerial wire system to cut down the wavelength.
- CONDENSITE.—A manufactured insulating compound.
- CONDUCTIVELY COUPLED.—Two circuits that are connected together by means of a single tuning coil or helix.
- CONDUCTIVITY.—The conductance of a given length of wire of uniform cross section. The reciprocal of *resistivity*.
- CONTACT DETECTORS.—See *Detectors, Contact*.
- CONTINENTAL CODE.—See *Code, Continental*.
- CONVECTIVE DISCHARGE.—See *Discharge*.
- CONVENTIONAL SIGNALS.—See *Signals, Conventional*.
- COULOMB.—The quantity of electricity transferred by a current of 1 ampere in 1 second.
- COUNTER ELECTROMOTIVE FORCE.—See *Electromotive Force, Counter*.
- COUNTERPOISE.—A duplicate of the aerial wire that is raised a few feet above the earth and insulated from it. Usually no connection is made with the earth itself.
- COUPLED CIRCUITS.—See *Circuit, Coupled*.
- COUPLING.—When two oscillation circuits are connected together either by the magnetic field of an inductance coil, or by the electrostatic field of a condenser.
- COUPLING, CAPACITIVE.—Oscillation circuits when connected together by condensers instead of inductance coils.
- COUPLING, COEFFICIENT OF.—The measure of the closeness of the coupling between two coils.
- COUPLING, INDUCTIVE.—Oscillation circuits when connected together by inductance coils.
- COUPLING, RESISTANCE.—Oscillation circuits connected together by a resistance.
- CRYSTAL RECTIFIER.—A crystal detector.
- CURRENT, ALTERNATING (A.C.).—A low-frequency current that surges to and fro in a circuit.

CURRENT, AUDIO-FREQUENCY.—A current whose frequency is low enough to be heard in a telephone receiver. Such a current usually has a frequency of between 60 and 5,000 cycles per second.

CURRENT, DIRECT.—An electric current that flows in one direction only.

CURRENT, PLATE.—The current which flows between the filament and the plate of a vacuum tube.

CURRENT, PULSATING.—A direct current whose voltage varies from moment to moment.

CURRENT, RADIO-FREQUENCY.—A current whose frequency is so high it cannot be heard in a telephone receiver. Such a current may have a frequency of from 20,000 to 10,000,000 per second.

CURRENTS, HIGH-FREQUENCY.—(1) Currents that oscillate from 10,000 to 300,000,000 times per second. (2) Electric oscillations.

CURRENTS, HIGH-POTENTIAL.—(1) Currents that have a potential of more than 10,000 volts. (2) High-voltage currents.

CYCLE.—(1) A series of changes which when completed are again at the starting point. (2) A period of time at the end of which an alternating or oscillating current repeats its original direction of flow.

DAMPING.—The degree to which the energy of an electric oscillation is reduced. In an open circuit the energy of an oscillation set up by a spark gap is damped out in a few swings, while in a closed circuit it is greatly prolonged, the current oscillating 20 times or more before the energy is dissipated by the sum of the resistances of the circuit.

DECREMENT.—The act or process of gradually becoming less. The quantity lost by diminution.

DETECTOR.—Any device that will (1) change the oscillations set up by the incoming waves into direct current, that is which will rectify them, or (2) that will act as a relay.

Carborundum.—One that uses a *carborundum* crystal for the sensitive element. Carborundum is a crystalline silicon carbide formed in the electric furnace.

Chalcopyrite.—Copper pyrites. A brass colored mineral used as a crystal for detectors. See *Zincite*.

Contact.—A crystal detector. Any kind of a detector in which two dissimilar but suitable solids make contact.

Ferron.—A detector in which iron pyrites are used as the sensitive element.

Galena.—A detector that uses a galena crystal for the rectifying element.

Iron Pyrites.—A detector that uses a crystal of iron pyrites for its sensitive element.

Molybdenite.—A detector that uses a crystal of *sulphide of molybdenum* for the sensitive element.

Perikon.—A detector in which a *bornite* crystal makes contact with a *zincite* crystal.

Silicon.—A detector that uses a crystal of silicon for its sensitive element.

Vacuum Tube.—A vacuum tube (which see) used as a detector.

Zincite.—A detector in which a crystal of *zincite* is used as the sensitive element.

DE-TUNING.—A method of signaling by sustained oscillations in which the key when pressed down cuts out either some of the inductance or some of the capacity and hence greatly changes the wavelength.

DIELECTRIC.—An insulating material between two electrically charged plates in which there is set up an *electric strain*, or displacement.

DIELECTRIC STRAIN.—The electronic displacement in a dielectric.

DIRECTION FINDER.—See *Aerial, Loop*.

DIRECTIONAL AERIAL.—See *Aerial, Directional*.

DISCHARGE.—(1) A faintly luminous discharge that takes place from the positive pointed terminal of an induction coil, or other high potential apparatus; is termed a *brush discharge*. (2) A continuous discharge between the terminals of a high potential apparatus is termed a *convective discharge*. (3) The sudden breaking-down of the air between the balls forming the spark gap is termed a *disruptive discharge*; also called an *electric spark*, or just *spark* for short. (4) When

a tube has a poor vacuum, or too large a battery voltage, it glows with a blue light and this is called a *blue glow discharge*.

DISRUPTIVE DISCHARGE.—See *Discharge*.

DISTRESS CALL. . . . — — — . . . (S O S).

DISTRIBUTED CAPACITY.—See *Capacity, Distributed*.

DOUBLE HUMP RESONANCE CURVE.—A resonance curve that has two peaks or humps which show that the oscillating currents which are set up when the primary and secondary of a tuning coil are closely coupled have two frequencies.

DUO-LATERAL COILS.—See *Coils, Inductance*.

DUPLEX COMMUNICATION.—A radio telephone system with which it is possible to talk between both stations in either direction without the use of switches.

EARTH CAPACITY.—An aerial counterpoise.

EARTH CONNECTION.—Metal plates or wires buried in the ground or immersed in water. Any means by which the sending and receiving apparatus can be connected with the earth.

EDISON STORAGE BATTERY.—See *Storage Battery, Edison*.

ELECTRIC ENERGY.—The power of an electric current.

ELECTRIC OSCILLATIONS.—See *Oscillations, Electric*.

ELECTRIC SPARK.—See *Discharge, Spark*.

ELECTRICITY, NEGATIVE.—The opposite of *positive electricity*. Negative electricity is formed of negative electrons which make up the inside particles of an atom.

ELECTRICITY, POSITIVE.—The opposite of *negative electricity*. Positive electricity is formed of positive electrons which make up the inside particles of an atom.

ELECTRODES.—Usually the parts of an apparatus which dip into a liquid and carry a current. The electrodes of a dry battery are the zinc and carbon elements. The electrodes of an Edison storage battery are the iron and nickel elements, and the electrodes of a lead storage battery are the lead elements.

ELECTROLYTES.—The acid or alkaline solutions used in batteries.

ELECTROMAGNETIC WAVES.—See *Waves, Electric*.

- ELECTROMOTIVE FORCE.**—Abbreviated *emf.* The force that drives an electric current along a conductor. Also loosely called *voltage*.
- ELECTROMOTIVE FORCE, COUNTER.**—The *emf.* that is set up in a direction opposite to that in which the current is flowing in a conductor.
- ELECTRON.**—(1) A negative particle of electricity that is detached from an atom. (2) A negative particle of electricity thrown off from the incandescent filament of a vacuum tube.
- ELECTRON FLOW.**—The passage of electrons between the incandescent filament and the cold positively-charged plate of a vacuum tube.
- ELECTRON RELAY.**—See *Relay, Electron*.
- ELECTRON TUBE.**—A vacuum tube or a gas-content tube used for any purpose in radio or other work. See *Vacuum Tube*.
- ELECTROSE INSULATORS.**—Insulators made of a composition material the trade name of which is *Electrose*.
- ENERGY, ELECTRIC.**—See *Electric Energy*.
- ENERGY UNIT.**—The *joule*, which see, *page 305*.
- FADING.**—The sudden variation in strength of signals received from a transmitting station when all the adjustments of both sending and receiving apparatus remain the same. Also called *swinging*.
- FARAD.**—The capacity of a condenser in which a potential difference of 1 volt causes it to have a charge of 1 coulomb of electricity.
- FEED-BACK ACTION.**—Feeding back the oscillating currents in a vacuum tube to amplify its power. Also called *regenerative action*.
- FERROMAGNETIC CONTROL.**—See *Magnetic Amplifier*.
- FILAMENT.**—The wire in a vacuum tube that is heated to incandescence and which throws off electrons.
- FILAMENT RHEOSTAT.**—See *Rheostat, Filament*.
- FILTER.**—Inductance coils or condensers or both which (1) prevent troublesome voltages from acting on the different

circuits, and (2) smooth out alternating currents after they have been rectified.

FILTER REACTOR.—See *Reactor, Filter*.

FIRE UNDERWRITERS.—See *Code, National Electric*.

FIXED GAP.—See *Gap*.

FLEMING VALVE.—A two-electrode vacuum tube, containing filament and plate only.

FORCED OSCILLATIONS.—See *Oscillations, Forced*.

FREE OSCILLATIONS.—See *Oscillations, Free*.

FREQUENCY, AUDIO.—(1) An alternating current whose frequency is low enough to operate a telephone receiver and, hence, which can be heard by the ear. (2) Audio-frequencies are usually around 500 or 1,000 cycles per second, but may be as low as 14 and as high as 14,000 cycles per second.

Carrier.—A radio-frequency wave modulated by an audio-frequency wave which results in setting of *three* radio frequency waves. The principal radio frequency is called the *carrier frequency*, since it *carries* or transmits the audio-frequency wave.

Commercial.—(1) Alternating current that is used for commercial purposes, namely, *light, heat* and *power*. (2) Commercial frequencies now in general use are from 25 to 60 cycles per second.

Natural.—The pendulum and vibrating spring have a *natural frequency* which depends on the size, material of which it is made, and the friction which it has to overcome. Likewise an oscillation circuit has a *natural frequency* which depends upon its *inductance, capacity* and *resistance*.

Radio.—(1) An oscillating current whose frequency is too high to affect a telephone receiver and, hence, cannot be heard by the ear. (2) Radio-frequencies are usually between 20,000 and 2,000,000 cycles per second but may be as low as 10,000 and as high as 300,000,000 cycles per second.

Spark.—The number of sparks per second produced by the discharge of a condenser.

GAP, FIXED.—One with fixed electrodes.

- GAP, NON-SYNCHRONOUS.**—A rotary spark gap run by a separate motor at a speed which may be widely different from that of the alternator.
- GAP, QUENCHED.**—(1) A spark gap for the impulse production of oscillating currents. (2) This method can be likened to one where a spring is struck a single sharp blow and then continues to set up vibrations.
- GAP, ROTARY.**—One having fixed and rotating electrodes.
- GAP, SYNCHRONOUS.**—A rotary spark gap run at the same speed as the alternator which supplies the power transformer. Such a gap usually has as many teeth as there are poles on the generator. Hence one spark occurs per half cycle.
- GAS-CONTENT TUBE.**—See *Vacuum Tube*.
- GENERATOR TUBE.**—A vacuum tube used to set up oscillations. As a matter of fact it does not *generate* oscillations, but changes the initial low-voltage current that flows through it into oscillations. Also called an *oscillator tube* and a *power tube*.
- GRID.**—(1) The metal gauze element placed between the filament and the plate of a vacuum tube. It controls the current flowing from the filament to the plate. (2) One of the perforated lead plate elements of a storage battery.
- GRID BATTERY.**—See *Battery C*.
- GRID CIRCUIT.**—The circuit in which the grid of a vacuum tube is connected.
- GRID CHARACTERISTICS.**—The various relations that could exist between the voltages and currents of the grid of a vacuum tube, and the values which do exist between them when the tube is in operation. These characteristics are generally shown by curves.
- GRID COIL.**—An inductance coil connected in series with the grid circuit.
- GRID CONDENSER.**—See *Condenser, Grid*.
- GRID LEAD.**—The wire or conductor that leads to and which is connected with the grid.
- GRID LEAK.**—A high-resistance unit connected in the grid lead of both transmitting and receiving sets. In a transmitter it keeps the voltage of the grid at a constant value and so

- controls the output of the aerial. In a receiving set it controls the current flowing between the plate and filament.
- GRID MODULATION.—See *Modulation, Grid*.
- GRID POTENTIAL.—The negative or positive voltage of the grid of a vacuum tube.
- GRID VOLTAGE.—See *Grid Potential*.
- GRINDERS.—The most common form of *Static*, which see. They make a grinding noise in the headphones.
- GROUND.—See *Earth Connection*.
- GROUND, AMATEUR.—A water-pipe ground.
- GROUND, WATER-PIPE.—A common method of grounding by amateurs is to use the water-pipe or radiator.
- GUIDED WAVE TELEPHONY.—See *Wired Wireless*.
- HARD TUBE.—A vacuum tube in which the vacuum is *high*, that is, exhausted to a high degree.
- HELIX.—(1) Any coil of wire. (2) Specifically a transmitter tuning inductance coil.
- HENRY.—The inductance in a circuit in which the electromotive force induced is 1 volt when the inducing current varies at the rate of 1 ampere per second.
- HETERODYNE RECEPTION.—(1) Receiving by the *beat* method. (2) Receiving by means of superposing oscillations generated at the receiving station on the oscillations set up in the aerial by the incoming waves.
- HETERODYNE RECEPTOR.—See *Receptor, Heterodyne*.
- HIGH-FREQUENCY CURRENTS.—See *Currents, High-Frequency*.
- HIGH-FREQUENCY RESISTANCE.—See *Resistance, High-Frequency*.
- HIGH-POTENTIAL CURRENTS.—See *Currents, High-Potential*.
- HIGH-VOLTAGE CURRENTS.—See *Currents, High-Potential*.
- HONEYCOMB COILS.—See *Coils, Inductance*.
- HORSEPOWER.—Used in rating steam machinery. It is equal to 746 watts.
- HOT-WIRE AMMETER.—See *Ammeter, Hot-Wire*.
- HOWLING.—Where more than three stages of radio amplification, or more than two stages of audio amplification, are used howling noises are apt to occur in the telephone receivers.

- IMPEDANCE.**—An oscillation circuit has *reactance* and also *resistance*, and when these are combined the total opposition to the current is called *impedance*. Similar to resistance in direct-current work.
- INDUCTANCE COILS.**—See *Coils, Inductance*.
- INDUCTANCE COIL, LOADING.**—See *Coil, Loading Inductance*.
- INDUCTION COIL.**—See *Coil, Induction*.
- INDUCTION, MUTUAL.**—Induction produced between two.
- INDUCTIVE COUPLING.**—See *Coupling, Inductive*.
- INDUCTIVE REACTANCE.**—See *Reactance, Inductive*.
- INDUCTIVELY COUPLED.**—Circuits that are coupled together by means of a primary and secondary coil. Transformers are inductively coupled.
- INSPECTOR, RADIO.**—A U. S. inspector whose business it is to issue both station and operators' licenses in the district of which he is in charge.
- INSULATION.**—Materials used on and around wires and other conductors to keep the current from leaking away.
- INTERFERENCE.**—The crossing or superposing of two sets of electric waves of the same or slightly different lengths which tend to oppose each other. It is the interference between electric waves from different stations that makes selective signaling so difficult a problem.
- INTERMEDIATE WAVES.**—See *Waves*.
- INTERNATIONAL CODE.**—See *Code, International*.
- IONIC TUBES.**—See *Vacuum Tubes*.
- JACK.**—A spring contact receptacle into which a plug is inserted completing a circuit through the device connected to the plug.
- JAMMING.**—Waves that are of such length and strength that when they interfere with incoming waves they drown them out.
- JOULE.**—The energy spent in 1 second by a flow of 1 ampere in 1 ohm.
- JOULE'S LAW.**—The relation between the heat produced in a circuit and the resistance of the circuit. The amount of current flowing and the number of seconds the current flows.

- KENOTRON.**—The trade name of a vacuum tube rectifier made by the *Radio Corporation of America*.
- KICK-BACK.**—Oscillating currents that rise in voltage and tend to flow back through a low-voltage circuit.
- KICK-BACK PREVENTION.**—See *Prevention, Kick-Back*.
- KILOCYCLES.**—A thousand cycles. See *Cycle*.
- KILOWATT.**—1,000 watts.
- LATTICE WOUND COILS.**—See *Coils, Inductance*.
- LEAD.**—A wire or other conductor that leads to and is connected with a piece of apparatus.
- LIGHTNING SWITCH.**—See *Switch, Lightning*.
- LINE RADIO COMMUNICATION.**—See *Wired Wireless*.
- LINE RADIO TELEPHONY.**—See *Telephony, Line Radio*.
- LITZENDRAHT.**—A conductor formed of a number of fine insulated copper wires either twisted or braided together. It is used to reduce the *skin effect*. See *Resistance, High-Frequency*.
- LOAD FLICKER.**—The flickering of electric lights on lines that supply radio transmitting sets due to variations of the voltage on opening and closing the key.
- LOADING COIL.**—See *Coil, Loading*.
- LONG WAVES.**—See *Waves*.
- LOOP AERIAL.**—See *Aerial, Loop*.
- LOOSE COUPLED CIRCUITS.**—See *Circuits, Loose Coupled*.
- LOOSE COUPLER.**—See *Coils, Conductance*.
- LOUD SPEAKER.**—A device that changes electrical energy into sound energy and reproduces the incoming signals, words or music loud enough to be heard by a room or an auditorium full of people, or by large crowds outdoors.
- MAGNETIC POLES.**—See *Poles, Magnetic*.
- MEGOHM.**—One million ohms.
- METER, AUDIBILITY.**—An instrument for measuring the loudness of a signal by comparison with another signal. It consists of a pair of headphones and a variable resistance which has been calibrated.
- MHO.**—The unit of conductance. As conductance is the re-

- reciprocal of resistance it is measured by the *reciprocal ohm* or *mho*.
- MICA. A transparent mineral having a high insulating value and which can be split into very thin sheets. It is largely used in making condensers both for transmitting and receiving sets.
- MICROAMPERE.—A millionth of an ampere.
- MICROFARAD.—The millionth part of a *farad*.
- MICROHENRY.—The millionth part of a *henry*.
- MICROHM.—The millionth part of an *ohm*.
- MICROMICROFARAD.—The millionth part of a *microfarad*.
- MICROPHONE TRANSFORMER.—See *Transformer, Microphone*.
- MICROPHONE TRANSMITTER.—See *Transmitter, Microphone*.
- MILLI-AMMETER.—An ammeter that measures a current by the one-thousandth of an ampere.
- MILLIAMPERE.—The one-thousandth of an ampere.
- MILLIHENRY.—The thousandth part of a *henry*.
- MODULATION.—(1) Inflection or varying the voice (2) Varying the amplitude of oscillations by means of the voice.
- MODULATION, BUZZER.—The modulation of radio-frequency oscillations by a buzzer which breaks up the sustained oscillations of a transmitter into audio-frequency impulses.
- MODULATION, CHOPPER.—The modulation of radio-frequency oscillations by a chopper which breaks up the sustained oscillations of a transmitter into audio-frequency impulses.
- MODULATION, GRID.—The scheme of modulating an oscillator tube by connecting the secondary of a transformer, the primary of which is connected with a battery and a microphone transmitter, in the grid lead.
- MODULATION, OVER.—See *Blub Blub*.
- MODULATION, PLATE.—Modulating the oscillations set up by a vacuum tube by varying the current impressed on the plate.
- MODULATOR TUBE.—A vacuum tube used as a modulator.
- MOTION, WAVE.—(1) The to and fro motion of water at sea. (2) Waves transmitted by, in and through the *air*, or sound waves. (3) Waves transmitted by, in and through the *ether*, or *electromagnetic waves*, or *electric waves* for short.

MOTOR-GENERATOR.—A motor and a dynamo built to run at the same speed and mounted on a common base, the shafts being coupled together. In radio it is used for changing commercial direct current into direct current of higher voltages for energizing the plate of a vacuum tube oscillator.

MULTI-STAGE AMPLIFIERS.—See *Amplifiers, Multi-Stage*.

MUTUAL INDUCTION.—See *Induction, Mutual*.

MUSH.—Irregular intermediate frequencies set up by arc transmitters which interfere with the fundamental wavelengths.

MUSHY NOTE.—A note that is not clear cut, and hence hard to read, which is received by the *heterodyne method* when damped waves or modulated continuous waves are being received.

NATIONAL ELECTRIC CODE.—See *Code, National Electric*.

NATIONAL ELECTRIC SAFETY CODE.—See *Code, National Electric Safety*.

NEGATIVE ELECTRICITY.—See *Electricity, Negative*.

NON-SYNCHRONOUS GAP.—See *Gap, Non-Synchronous*.

OHM.—The resistance of a thread of mercury at the temperature of melting ice, 14.4521 grams in mass, of uniform cross-section and a length of 106.300 centimeters.

OHM'S LAW.—The important fixed relation between the electric current, its electromotive force and the resistance of the conductor in which it flows.

OPEN CIRCUIT.—See *Circuit, Open*.

OPEN CORE TRANSFORMER.—See *Transformer, Open Core*.

OSCILLATION TRANSFORMER.—See *Transformer, Oscillation*.

OSCILLATION VALVE.—See *Vacuum Tube*.

OSCILLATIONS, ELECTRIC.—A current of high-frequency that surges through an open or a closed circuit. (1) Electric oscillations may be set up by a spark gap, electric arc or a vacuum tube, when connected with a circuit having inductance and capacity, when they have not only a high frequency but a high-potential, or voltage. (2) When electric waves impinge on an aerial wire they are transformed into electric oscillations of a frequency equal to those

which emitted the waves, but since a very small amount of energy is received their potential or voltage is likewise very small.

Sustained.—Oscillations in which the damping factor is small.

Damped.—Oscillations in which the damping factor is large.

Free.—When a condenser discharges through an oscillation circuit, where there is no outside electromotive force acting on it, the oscillations are said to be *free*.

Forced.—Oscillations that are made to surge in a circuit whose natural period is different from that of the oscillations set up in it.

OSCILLATOR TUBE.—A vacuum tube which is used to produce electric oscillations.

OSCILLOGRAPH.—A device for making visible or photographing the wave forms of alternating voltages or currents.

OVER MODULATION.—See *Blub Blub*.

PANCAKE OSCILLATION TRANSFORMER.—Disk-shaped coils that are used for receiving tuning inductances.

PERIOD.—The length of time needed for one complete cycle of oscillation.

PERMEABILITY, MAGNETIC.—The degree to which a substance can be magnetized. Iron has a greater magnetic permeability than air.

PHASE.—A characteristic aspect or appearance that takes place at the same point or part of a cycle.

PICK-UP CIRCUITS.—See *Circuits, Stand-By*.

PLATE.—One of the elements of a vacuum tube.

PLATE CIRCUIT.—The circuit in which the plate of a vacuum tube is connected.

PLATE CIRCUIT REACTOR.—See *Reactor, Plate Circuit*.

PLATE CURRENT.—See *Current, Plate*.

PLATE MODULATION.—See *Modulation, Plate*.

PLATE VOLTAGE.—See *Voltage, Plate*.

PLUG.—A device for connecting another device into a circuit in which a jack is wired.

POLES, BATTERY.—The positive and negative terminals of the elements of a battery. On a storage battery these poles are marked + and - respectively.

POLES, MAGNETIC.—The ends of a magnet.

POSITIVE ELECTRICITY.—See *Electricity, Positive*.

POTENTIAL DIFFERENCE.—The electric pressure between two charged conductors or surfaces.

POTENTIOMETER.—A variable resistance used for subdividing a voltage. A *voltage divider*.

POWER TRANSFORMER.—See *Transformer, Power*.

POWER TUBE.—See *Generator Tube*.

PREVENTION, KICK-BACK.—A choke coil placed in the power circuit to prevent the high-frequency currents from getting into the transformer and breaking down the insulation.

PRIMARY.—The input coil or circuit of a transformer.

PRIMARY BATTERY.—See *Battery, Primary*.

Q S T.—An abbreviation used in wireless communication for (1) the question "Have you received the general call?" and (2) the notice, "General call to all stations."

QUENCHED GAP.—See *Gap, Quenched*.

RADIATION.—The emission, or throwing off, of electric waves by an aerial wire system.

RADIO AMMETER.—See *Ammeter, Hot-Wire*.

RADIO BEACON.—A transmitter continually operating for use in direction finding.

RADIO COMPASS.—A receiver using a loop antenna calibrated to indicate the direction from which a signal comes.

RADIO-FREQUENCY.—See *Frequency, Radio*.

RADIO-FREQUENCY AMPLIFICATION.—See *Amplification, Radio-Frequency*.

RADIO-FREQUENCY CURRENT.—See *Current, Radio-Frequency*.

RADIO INSPECTOR.—See *Inspector, Radio*.

RADIOMOVIES.—The process of transmitting of images by radio from films of persons or scenes in motion.

RADIOVISION.—The transmitting of images by radio from living subjects.

- RADIO WAVES.**—See *Waves, Radio*.
- REACTANCE.**—When a circuit has inductance and the current changes in value, it is opposed by the voltage induced by the variation of the current.
- REACTANCE, CAPACITY.**—The capacity reactance is the opposition offered to a current by a capacity. It is measured as a resistance, that is, in *ohms*.
- REACTANCE, INDUCTIVE.**—The inductive reactance is the opposition offered to the current by an inductance coil. It is measured as a resistance, that is, in *ohms*.
- REACTOR.**—A coil wound on an iron core which opposes the flow of a current by its counter electromotive force.
- REACTOR, FILTER.**—A reactance coil for smoothing out the pulsating direct currents as they come from the rectifier. A choke coil will act as a reactor.
- REACTOR, PLATE CIRCUIT.**—A reactance coil used in the plate circuit of a radio telephone to keep the direct current supply at a constant voltage.
- RECEIVER.**—(1) A telephone receiver. (2) An apparatus for receiving signals, speech or music.
- RECEIVER, AUTODYNE.**—A receiver that has a regenerative circuit and the same tube is used as a detector and as a generator of local oscillations.
- RECEIVER, BEAT.**—A heterodyne receiver.
- RECEIVER, HETERODYNE.**—A receiving set that uses a separate vacuum tube to set up the second series of waves for beat reception.
- RECEIVER, LOUD SPEAKING.**—See *Loud Speakers*.
- RECEIVER, WATCH CASE.**—A compact telephone receiver used for radio reception.
- RECEIVING TUNING COILS.**—See *Coils, Inductance*.
- RECTIFIER.**—(1) An apparatus for changing alternating current into pulsating direct current. (2) Specifically in radio (a) a crystal or vacuum tube detector, and (b) a two-electrode vacuum tube used for changing commercial alternating current into direct current for radio telephony.
- REGENERATIVE ACTION.**—See *Feed-Back Action*.
- REGENERATIVE AMPLIFICATION.**—See *Amplification, Regenerative*.

- RELAY, ELECTRON.—A vacuum tube when used as a detector or an amplifier.
- REPEATING COIL.—A transformer used in connecting up a radio receiver with a wire transmitter.
- RESISTANCE.—The opposition offered by a wire or other conductor to the passage of a current.
- RESISTANCE, AERIAL.—The resistance of the aerial wire to oscillating currents. This is greater than its ordinary ohmic resistance due to the skin effect. See *Resistance, High-Frequency*.
- RESISTANCE BOX.—See *Resistor*.
- RESISTANCE BRIDGE.—An apparatus for measuring the resistance (in ohms) of a circuit.
- RESISTANCE COIL.—A coil made of wire that has a high resistance, as German silver, and which is used to vary the strength of the current flowing through a circuit.
- RESISTANCE COUPLING.—See *Coupling, Resistance*.
- RESISTANCE, HIGH-FREQUENCY.—When a high-frequency current oscillates on a wire two things take place that are different than when a direct or alternating current flows through it, and these are (1) the current inside of the wire lags behind the current on the surface, and (2) the amplitude of the current is largest on the surface and grows smaller as the center of the wire is reached. This uneven distribution of the current is known as the *skin effect* and it amounts to the same thing as reducing the size of the wire, hence the resistance is increased.
- RESISTIVITY.—The resistance of a given length of wire of uniform cross section. The reciprocal of *conductivity*.
- RESISTOR.—A fixed or variable resistance unit or a group, of such units. Variable resistors are also called *resistance boxes* and more often *rheostats*.
- RESONANCE.—(1) Simple resonance of sound is its increase set up by one body by the sympathetic vibration of a second body. (2) By extension the increase in the amplitude of electric oscillations when the circuit in which they surge has a *natural* period that is the same, or nearly the same, as the period of the first oscillation circuit.

- RHEOSTAT.**—A variable resistance unit. See *Resistor*.
- RHEOSTAT, CARBON.**—A carbon rod, or carbon plates or blocks, when used as variable resistances.
- RHEOSTAT, FILAMENT.**—A variable resistance used for keeping the current of the storage battery which heats the filament of a vacuum tube at a constant voltage.
- ROTARY GAP.**—See *Gap*.
- ROTATING COIL.**—See *Coil*.
- ROTOR.**—The rotating coil of a variometer or a variocoupler.
- RUHMKORFF COIL.**—See *Coil, Induction*.
- SATURATION.**—The maximum plate current that a vacuum tube will take.
- SCREEN-GRID VACUUM TUBE.**—See *Vacuum Tube*.
- SECONDARY.**—The output coil or circuit of a transformer.
- SENSITIVE SPOTS.**—Spots on detector crystals that are sensitive to the action of electric oscillations.
- SHIELD.**—A metal box or cylinder placed around one or more instruments and grounded, to prevent changes in capacity within the enclosed circuits.
- SHORT WAVES.**—See *Waves*.
- SIDE WAVES.**—See *Wavelength Band*.
- SIGNALS, CONVENTIONAL.**—(1) The International Morse alphabet and numeral code, punctuation marks, and a few important abbreviations. (2) Dot and dash signals for distress call, etc.
- SKIN EFFECT.**—See **RESISTANCE, HIGH-FREQUENCY**.
- SOCKET POWER UNIT.**—A device that will furnish "A," "B," and "C" battery power from the houselighting line. Usually consists of a rectifier and filter.
- SOFT TUBE.**—A vacuum tube in which the vacuum is *low*, that is, it is not highly exhausted.
- SPACE CHARGE EFFECT.**—The electric field intensity due to the pressure of the negative electrons in the space between the filament and plate which at last equals and neutralizes that due to the positive potential of the plate so that there is no force acting on the electrons near the filament.
- SPARK.**—See *Discharge*.

SPARK COIL.—See *Coil, Induction*.

SPARK DISCHARGE.—See *Spark, Electric*.

SPARK FREQUENCY.—See *Frequency, Spark*.

SPARK GAP.—(1) A *spark gap*, without the hyphen, means the apparatus in which sparks take place; it is also called a *spark discharger*. (2) *Spark-gap*, with the hyphen, means the air-gap between the opposed faces.

Plain.—A spark gap with fixed electrodes.

Rotary.—A spark gap with a pair of fixed electrodes and a number of electrodes mounted on a rotating element.

Quenched.—A spark gap formed of a number of metal plates placed closely together and insulated from each other.

SPIDER WEB INDUCTANCE COIL.—See *Coil, Spider Web Inductance*.

SPREADER.—A stick of wood, or spar, that holds the wires of the aerial apart.

STAGGER WOUND COILS.—See *Coils, Inductance*.

STAND-BY CIRCUITS.—See *Circuits, Stand-By*.

STATIC.—Also called *atmospherics, grinders, strays, X's*, and, when bad enough, by other names. It is an electrical disturbance in the atmosphere which makes noises in the telephone receiver.

STATOR.—The fixed or stationary coil of a variometer or a variocoupler.

STRAIGHT LINE FREQUENCY.—The term applied to condensers whose variable plates are cut in such a shape that if the frequency is plotted on graph paper against the dial settings the result will be a straight line. There are also dials for rotating the movable plates of the ordinary type of condenser, in such a way that the distance they move per scale unit varies throughout the length of the scale giving the same effect as a S. L. F. condenser.

STRANDED WIRE.—See *Wire, Stranded*.

STRAY ELIMINATION.—A method for increasing the strength of the signals as against the strength of the strays. See *Static*.

STRAYS.—See *Static*.

SUPERHETERODYNE RECEIVER.—See *Heterodyne, Super*.

SWINGING.—See *Fading*.

SWITCH, AERIAL.—A switch used to change over from the sending to the receiving set, and the other way about, and connect them with the aerial.

SWITCH, LIGHTNING.—The switch that connects the aerial with the outside ground when the apparatus is not in use.

SYMBOLS, APPARATUS.—Also called *conventional symbols*. These are diagrammatic lines representing various parts of apparatus so that when a wiring diagram of a transmitter or a receptor is to be made it is only necessary to connect them together. They are easy to make and easy to read. See page 280.

SYNCHRONOUS GAP.—See *Gap, Synchronous*.

TELEPHONY, LINE RADIO.—See *Wired Wireless*.

TELEVISION.—Sight at a distance, literally. The name applied to a system of radio whereby the image of an object can be transmitted by electrical impulses from one point to another on a carrier wave. This has become a more or less common name for Radiovision or Radiomovies, but strictly speaking Television is the transmission of images over wires not by means of a radio wave.

THERMAL AMMETER.—See *Ammeter, Hot-Wire*.

THREE ELECTRODE VACUUM TUBE.—See *Vacuum Tube, Three Electrode*.

TICKLER.—A third coil that forms part of the tuning coil and which feeds back part of the oscillating current to the detector tube in a regenerative receiving set.

TIKKER.—A slipping contact device that breaks up the sustained oscillations at the receiving end into groups so that the signals can be heard in the headphones.

TRANSFORMER.—A primary and a secondary coil for stepping up or down a primary alternating or oscillating current.

A.C.—See *Power Transformer*.

Air Cooled.—A transformer in which the coils are exposed to the air.

Air Core.—With high-frequency currents it is the general practice not to use iron cores as these tend to choke off

the oscillations. Hence the core consists of the air inside of the coils.

Auto.—A single coil of wire in which one part forms the primary and the other part the secondary by bringing out an intermediate tap.

Audio Amplifying.—This is a transformer with an iron core and is used for frequencies up to say 3,000.

Closed Core.—A transformer in which the path of the magnetic flux is entirely through iron. Power transformers have closed cores.

Microphone.—A small transformer for modulating the oscillations set up by an arc or a vacuum tube oscillator.

Oil Cooled.—A transformer in which the coils are immersed in oil.

Open Core.—A transformer in which the path of the magnetic flux is partly through iron and partly through air. Induction coils have open cores.

Oscillation.—A coil or coils for transforming or stepping down or up oscillating currents. Oscillation transformers usually have no iron cores when they are also called *air core transformers*.

Power.—A transformer for stepping down a commercial alternating current for lighting and heating the filament and for stepping up the commercial a.c., for charging the plate of a vacuum tube oscillator.

Radio Amplifying.—This is a transformer with an air core. It does not in itself amplify but is so called because it is used in connection with an amplifying tube.

TRANSMITTER, MICROPHONE.—A telephone transmitter of the kind that is used in the Bell telephone system.

TRANSMITTING TUNING COILS.—See *Coils, Inductance*.

TUNING.—When the open and closed oscillation circuits of a transmitter or a receptor are adjusted so that both of the former will permit electric oscillations to surge through them with the same frequency, they are said to be *tuned*. Likewise, when the sending and receiving stations are adjusted to the same wavelength they are said to be *tuned*.

Coarse Tuning.—The first adjustment in the tuning

oscillation circuits of a receptor is made with the inductance coil and this tunes them coarse, or roughly.

Fine Tuning.—After the oscillation circuits have been roughly tuned with the inductance coil the exact adjustment is obtained with the variable condenser and this is *fine tuning*.

Sharp.—When a sending set will transmit or a receiving set will receive a wave of given length only it is said to be sharply tuned. The smaller the decrement the sharper the tuning.

TUNING COILS.—See *Coils, Inductance*.

TWO-ELECTRODE VACUUM TUBE.—See *Vacuum Tube, Two Electrode*.

VACUUM TUBE.—A tube with two, three or four electrodes from which the air has been exhausted, or which is filled with an inert gas, and used as a detector, an amplifier, an oscillator or a modulator in wireless telegraphy and telephony.

Amplifier.—See *Amplifier, Vacuum Tube*.

Amplifying Modulator.—A vacuum tube used for modulating and amplifying the oscillations set up by the sending set.

Gas Content.—A tube made like a vacuum tube and used as a detector but which contains an inert gas instead of being exhausted.

Hard. See *Hard Tube*.

Heater Type.—A tube having its cathode heated by radiation from a separate filament, the power for which is alternating current.

Power.—A tube especially designed for use in the last stage of an audio-frequency amplifier.

Rectifier.—(1) A vacuum tube detector. (2) A two-electrode vacuum tube used for changing commercial alternating current into direct current for wireless telephony.

Screen-Grid.—A tube in which the plate is surrounded by a wire mesh.

Soft.—See *Soft Tube*.

Three Electrode.—A vacuum tube with three electrodes, namely a *filament*, a *grid* and a *plate*.

- Two Electrode.*—A vacuum tube with two electrodes, namely the *filament* and the *plate*.
- VALVE.—See *Vacuum Tube*.
- VALVE, FLEMING.—See *Fleming Valve*.
- VARIABLE CONDENSER.—See *Condenser, Variable*.
- VARIABLE INDUCTANCE.—See *Inductance, Variable*.
- VARIABLE RESISTANCE.—See *Resistance, Variable*.
- VARIOCOUPLER.—A tuning device for varying the inductance of the receiving oscillation circuits. It consists of a fixed and a rotatable coil whose windings are not connected with each other.
- VARIOMETER.—A tuning device for varying the inductance of the receiving oscillation currents. It consists of a fixed and a rotatable coil with the coils connected in series.
- VERNIER CONDENSER.—See *Condenser, Vernier*.
- VOLT.—The electromotive force which produces a current of 1 ampere when steadily applied to a conductor the resistance of which is one ohm.
- VOLTAGE DIVIDER.—See *Potentiometer*.
- VOLTAGE, PLATE.—The voltage of the current that is used to energize the plate of a vacuum tube.
- VOLTMETER.—An instrument for measuring the voltage of an electric current.
- WATCH CASE RECEIVER.—See *Receiver, Watch Case*.
- WATER-PIPE GROUND.—See *Ground, Water-Pipe*.
- WATT.—The power spent by a current of 1 ampere in a resistance of 1 ohm.
- WAVE, BROAD.—A wave having a high decrement, when the strength of the signals is nearly the same over a wide range of wavelengths.
- WAVELENGTH.—Every wave of whatever kind has a length. The wavelength is usually taken to mean the distance between the crests of two successive waves.
- WAVELENGTH BAND.—In radio reception when continuous waves are being sent out and these are modulated by a microphone transmitter the different audio frequencies set up corresponding radio frequencies and the energy of these

are emitted by the aerial; this results in waves of different lengths, or a *band* of waves as it is called.

WAVE METER.—An apparatus for measuring the lengths of electric waves set up in the oscillation circuits of sending and receiving sets.

WAVE MOTION.—Disturbances set up in the surrounding medium as water waves in and on the water, sound waves in the air and electric waves in the ether.

WAVES.—See *Wave Motion*.

WAVES, ELECTRIC.—Electromagnetic waves set up in and transmitted by and through the ether.

Continuous. *Abbreviated C.W.*—Waves that are emitted without a break from the aerial. Also called *undamped waves*.

Discontinuous.—Waves that are emitted periodically from the aerial. Also called *damped waves*.

Damped.—See *Discontinuous Waves*.

Intermediate.—Waves from 600 to 2,000 meters in length.

Long.—Waves over 2,000 meters in length.

Radio.—Electric waves used in wireless telegraphy and telephony.

Short.—Waves up to 600 meters in length.

Wireless.—Electric waves used in radio telegraphy and telephony.

Undamped.—See *Continuous Waves*.

WIRED WIRELESS.—Continuous waves of high-frequency that are sent over telephone or power wires instead of through space. Also called *line radio communication*, *carrier-frequency telephony*, *carrier-current telephony*, and *guided wave telephony*.

WIRE, ENAMELLED.—Wire that is given a thin coat of enamel which insulates it.

WIRE, PHOSPHOR BRONZE.—A very strong wire made of an alloy of copper and containing a trace of phosphorus.

WIRELESS TELEGRAPH CODE.—See *Code, International*.

X's.—See *Static*.

ZINCITE.—See *Detector*.

RADIO DON'TS

AERIAL WIRE DON'TS

Don't use iron wire for your aerial.

Don't fail to insulate it well at both ends.

Don't have it longer than 75 feet for sending out a 200-meter wave.

Don't fail to use a lightning arrester, or better, a lightning switch, for your receiving set.

Don't fail to use a lightning switch with your transmitting set.

Don't forget you must have an outside ground.

Don't fail to have the resistance of your aerial as small as possible. Use stranded wire.

Don't fail to solder the lead-in wire to the aerial.

Don't fail to insulate properly the lead-in wire where it goes through the window or wall.

Don't let your aerial or lead-in wire touch trees or other objects.

Don't let your aerial come too close to overhead wires of any kind.

Don't run your aerial directly under, or over, or parallel with electric light or other wires.

Don't fail to make a good ground connection with the water-pipe inside.

TRANSMITTING DON'TS

Don't attempt to send until you get your license.

Don't fail to live up to every rule and regulation.

Don't use an input of more than $\frac{1}{2}$ a kilowatt if you live within 5 nautical miles of a naval station.

Don't send on more than a 200-meter wave if you have a restricted or general amateur license.

Don't use spark gap electrodes that are too small or they will get hot.

Don't fail to use a safety spark gap between the grid and the filament terminals where the plate potential is above 2,000 volts.

Don't buy a motor-generator set if you have commercial alternating current in your home.

Don't overload an oscillation vacuum tube as it will greatly shorten its life. Use two in parallel.

Don't operate a transmitting set without a hot-wire ammeter in the aerial.

Don't use solid wire for connecting up the parts of transmitters. Use stranded or braided wire.

Don't fail to solder each connection.

Don't use soldering fluid, use rosin.

Don't think that all of the energy of an oscillation tube cannot be used for wavelengths of 200 meters and under. It can be if the transmitting set and aerial are properly designed.

Don't run the wires of oscillation circuits too close together.

Don't cross the wires of oscillation circuits except at right angles.

Don't set the transformer of a transmitting set nearer than 3 feet to the condenser and tuning coil.

Don't use a rotary gap in which the wheel runs out of true.

Don't fail to use alternating current for heating the filament where this is possible.

RECEIVING DON'TS

Don't expect to get as good results with a crystal detector as with a vacuum tube detector.

Don't be discouraged if you fail to hit the sensitive spot of a crystal detector the first time—or several times thereafter.

Don't use a wire larger than No. 30 for the wire electrode of a crystal detector.

Don't try to use a loud speaker with a crystal detector receiving set.

Don't expect a loop aerial to give worthwhile results with a crystal detector.

Don't handle crystals with your fingers as this destroys their sensitivity. Use tweezers or a cloth.

Don't imbed the crystal in solder as the heat destroys its sensitivity. Use *Wood's metal*, or some other alloy which melts at or near the temperature of boiling water.

Don't forget that strong static and strong signals sometimes destroy the sensitivity of crystals.

Don't heat the filament of a vacuum tube to greater brilliancy than is necessary to secure the sensitiveness required.

Don't use a plate voltage that is less or more than it is rated for.

Don't connect the filament to a lighting circuit.

Don't use dry cells for heating the filament except in a pinch.

Don't use a constant current to heat the filament, use a constant voltage.

Don't use a vacuum tube in a horizontal position unless it is made to be so used.

Don't fail to insulate properly the grid and plate leads.

Don't use more than 1/3 of the rated voltage on the filament and on the plate when trying it out for the first time.

Don't fail to use a voltmeter to find the proper temperature of the filament.

Don't expect to get results with a loud speaker when using a single vacuum tube.

Don't fail to protect your vacuum tubes from mechanical shocks and vibration.

Don't fail to cut off the *A* battery entirely from the filament when you are through receiving.

Don't expect to get the best results with a gas-content detector tube without using a potentiometer.

Don't connect a potentiometer across the *B* battery or it will speedily run down.

Don't expect to get as good results with a single coil tuner as you would with a loose coupler.

Don't expect to get as good results with a two-coil tuner as with one having a third, or *tickler*, coil.

Don't think you have to use a regenerative circuit, that is, one with a tickler coil, to receive with a vacuum tube detector.

Don't let your regenerative detector oscillate or howl when you are tuning the set. Those howls are being broadcast and your neighbors do not like to have their programs ruined.

Don't think you are the only amateur who is troubled with static.

Don't lay out or assemble your set on a panel first. Connect it up on a board and find out if everything is right.

Don't try to connect up your set without a wiring diagram in front of you.

Don't fail to shield radio-frequency amplifiers.

Don't set the axes of the cores of radio-frequency transformers in a line. Set them at right angles to each other.

Don't use wire smaller than No. 14 for connecting up the various parts.

Don't fail to adjust the B battery after putting in a fresh vacuum tube, as its sensitivity depends largely on the voltage.

Don't fail to space properly the parts where you use variometers.

Don't fail to put a copper shield between the variometer and the variocoupler.

Don't fail to keep the leads to the vacuum tube as short as possible.

Don't throw your receiving set out of the window if it *howls*. Try placing the audio-frequency transformers farther apart and the cores of them at right angles to each other.

Don't expect as good results with a loop aerial, or when using the bed springs, as an outdoor aerial will give you.

Don't use an amplifier having a plate potential of less than 100 volts for the last step where a loud speaker is to be used.

Don't try to assemble a set if you don't know the difference between a binding post and a blue print. Buy a set ready to use.

Don't expect to get Arlington time signals and the big stations if your receiver is made for short wavelengths.

Don't take your headphones apart. You are just as apt to spoil them as you would a watch.

Don't expect to get results with a Bell telephone receiver.

Don't forget that there are other operators using the ether besides yourself.

Don't let your B battery get damp and don't let it freeze.

Don't try to recharge your B battery unless it is constructed for the purpose.

STORAGE BATTERY DON'TS

Don't connect a source of alternating current direct to your storage battery. You have to use a rectifier.

Don't connect the positive lead of the charging circuit with the negative terminal of your storage battery.

Don't let the electrolyte get lower than the tops of the plates of your storage battery.

Don't fail to look after the condition of your storage battery once in a while.

Don't use a 6-volt storage battery for lighting the filaments of vacuum tubes that require only 1 1/2 or 4 volts.

Don't fail to keep the specific gravity of the electrolyte of your storage battery between 1.225 and 1.300 Baumé. This you can do with a hydrometer.

Don't fail to recharge your storage battery when the hydrometer shows that the specific gravity of the electrolyte is close to 1.225.

Don't keep charging the battery after the hydrometer shows that the specific gravity is 1.285.

Don't let the storage battery freeze.

Don't let it stand for longer than a month without using unless you charge it.

Don't monkey with the storage battery except to add a little distilled water to the electrolyte from time to time. If anything goes wrong with it better take it to a service station and let the expert do it.

EXTRA DON'TS

Don't think you have an up-to-date transmitting station unless you are using C.W.

Don't use a wire from your lightning switch down to the outside ground that is smaller than No. 4.

Don't try to operate your spark coil with 110-volt direct lighting current without connecting in a rheostat.

Don't try to operate your spark coil with 110-volt alternating lighting current without connecting in an electrolytic interruptor.

Don't try to operate an alternating current power transformer

with 110-volt direct current without connecting in an electrolytic interruptor.

Don't—no never—connect one side of the spark gap to the aerial wire and the other side of the spark gap to the ground. The Government won't have it—that's all.

Don't try to tune your transmitter to send out waves of given length by guesswork. Use a wavemeter.

Don't use *hard fiber* for panels. It is a very poor insulator where high-frequency currents are used.

Don't think you are the only one who doesn't know all about radio. It is a very complex art and there are many things that those experienced have still to learn.

**REGULATIONS OF THE NATIONAL BOARD OF
FIRE UNDERWRITERS FOR ELECTRIC WIR-
ING AND APPARATUS AS RECOMMENDED
BY THE NATIONAL FIRE PROTECTION
ASSOCIATION**

*American Standard Approved Aug. 18, 1931, by American
Standards Association (Effective Nov. 1, 1931)*

ARTICLE 37. RADIO EQUIPMENT

3701. General.

a. The requirements of this article shall neither apply to equipment installed on shipboard, nor to antennas used for coupling carrier current to line conductors; but shall be deemed to be additional to, or amendatory of, those prescribed in Articles 1 to 19, inclusive, of this code.

b. Transformers, voltage reducers, keys and other devices employed shall be of types expressly approved for radio reception or transmission.

c. Methods of wiring from the source of power to and between devices, related to apparatus connected to interior wiring systems, shall be in accordance with the rules covering permanent or portable fixtures, devices and appliances.

It is recommended that the authority enforcing this code be freely consulted as to the specific methods to be followed in any case of doubt relative to installation of antenna and counterpoise conductors and that the National Electrical Safety Code, Part 5, be followed.

3702. For Receiving Stations Only.

a. Antenna and counterpoise conductor sizes shall be not less than No. 14 if of copper or No. 17 if of bronze or copper-clad steel. Antenna and counterpoise conductors outside buildings

shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

b. Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

c. Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

d. The preceding paragraphs a, b, and c, shall not apply to light and power circuits used as receiving antenna, but the devices used to connect the light and power wires to radio receiving sets shall be of approved type.

e. Lead-in conductors, that is, conductors from antennas to sets, shall be of copper, approved copper-clad steel or other metal which will not corrode excessively, and in no case shall they be smaller than No. 14, except that bronze or copper-clad steel not less than No. 17 may be used.

f. Lead-in conductors from the antenna to the first building attachment shall conform to the requirements for antennas similarly located. Lead-in conductors from the first building attachment to the building entrance shall, except as specified in the following paragraph, be installed and maintained so that they cannot swing closer to open supply conductors than the following distances:

- Supply wires 0 to 600 volts..... 2 feet
- Supply wires exceeding 600 volts.....10 feet

Where all conductors involved are supported so as to insure a permanent separation and the supply wires do not exceed 150 volts to ground, the clearance may be reduced to not less than 4

inches. Lead-in conductors on the outside of buildings shall not come nearer than the clearances specified above to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor which will maintain permanent separation. The non-conductor shall be in addition to any insulating covering on the wire.

g. Each lead-in conductor shall enter the building through a non-combustible, non-absorptive, insulating bushing slanting upward toward the inside or by means of an approved device designed to give adequate insulation and protection. The lead-in conductor from the building entrance to the set shall have rubber insulation approved for voltages 0-600 (Type R).

h. Each lead-in conductor shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of 500 volts or less, properly connected and located either inside the building at some point between the entrance and the set which is convenient to a ground, or outside the building as near as practicable to the point of entrance. The protector shall not be placed in the immediate vicinity of easily ignitable stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.

i. If an antenna grounding switch is employed, it shall in its closed position form a shunt around the protective device. The switch should be placed in the most direct line between the lead-in conductor and the point where the grounding connection is made. Such a switch shall not be used as a substitute for the protective device.

j. If fuses are used they shall not be placed in the circuit from the antenna through the protective device to ground.

k. The protective grounding conductor may be bare and shall be of copper, bronze or approved copper-clad steel. The protective grounding conductor shall be not smaller nor have less conductance per unit of length, than the lead-in conductor, and in no case shall be smaller than No. 14 if of copper nor smaller than No. 17 if of bronze or copper-clad steel. The pro-

tective grounding conductor shall be run in as straight a line as possible from the protective device to a good permanent ground. The ground connections shall be made to a cold-water pipe where such pipe is available and is in service and connected to the street mains. An outlet pipe from a water tank fed from a street main or a well may be used, provided such outlet pipe is adequately bonded to the inlet pipe connected to the street water main or well. If water pipes are not available, ground connections may be made to a grounded steel frame of a building or to an artificial ground such as a galvanized iron pipe or a rod driven into permanently damp earth or to a metal plate or other body of metal buried similarly. Gas piping shall not be used for the ground.

l. The protective grounding conductor shall be guarded where exposed to mechanical injury. An approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping.

m. The protective grounding conductor may be run either inside or outside the building. The protective grounding conductor and ground, installed as prescribed in the preceding paragraphs *k* and *l*, may be used as the operating ground.

It is recommended that in this case the operating grounding conductor be connected to the ground terminal of the protective device.

If desired, a separate operating grounding connection and ground may be used, this operating grounding conductor being either bare or provided with an insulated covering.

n. Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than 2 inches to any electric light or power wire not in conduit unless separated therefrom by some continuous and firmly fixed non-conductor, such as porcelain tubes or approved flexible tubing, making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire.

o. Storage battery leads shall consist of conductors having approved rubber insulation. The circuit from a filament, "A," storage battery of more than 20 ampere-hours capacity, NEMA

rating, shall be properly protected by a fuse or circuit-breaker rated at not more than 15 amperes. The circuit from a plate, "B," storage battery shall be properly protected by a fuse or circuit-breaker rated at not more than 1 ampere in the negative lead. Fuses or circuit-breakers shall be located not more than 18 inches along the wire from a battery terminal.

3703. *For Transmitting Stations Only.*

a. Antenna and counterpoise conductors outside buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions. Antenna and counterpoise conductors where placed in proximity to electric light or power wires or less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

b. Antenna conductor sizes shall be not less than given in the following table:

| Material | Stations to which power supplied is less than 100 watts and where voltage of power is less than 400 volts | Stations to which power supplied is more than 100 watts or voltage of power is more than 400 volts |
|----------------------------------|--|---|
| Soft copper..... | 14 | 7 |
| Medium-drawn copper..... | 14 | 8 |
| Hard-drawn copper..... | 14 | 10 |
| Bronze or copper-clad steel..... | 14 | 12 |

c. Splices and joints in the antenna and counterpoise span shall be soldered unless made with approved splicing devices.

d. Lead-in conductors shall be of copper, bronze, approved copper-clad steel or other metal which will not corrode excessively and in no case shall be smaller than No. 14.

e. Antenna and counterpoise conductors and wires leading therefrom to ground switch, where attached to buildings, shall be firmly mounted 5 inches clear of the surface of the building, on non-absorptive insulating supports such as treated pins or brackets, equipped with insulators having not less than 5 inches creepage and air-gap distance to inflammable or conducting material, except that the creepage and air-gap distance for continuous-wave sets of 1000 watts and less input to the transmitter, shall be not less than 3 inches.

f. In passing the antenna or counterpoise lead-in into the building a tube or bushing of non-absorptive, insulating material, slanting upward toward the inside, shall be used and shall be so insulated as to have a creepage and air-gap distance in the case of continuous-wave sets of 1000 watts and less input to the transmitter, not less than 3 inches, and in all other cases not less than 5 inches. If porcelain or other fragile material is used it shall be protected where exposed to mechanical injury. A drilled window pane may be used in place of a bushing provided creepage and air-gap distances as specified above are maintained.

g. A double-throw knife switch having a break distance of at least 4 inches and a blade not less than $1/8$ inch by $1/2$ inch, or a flexible grounding lead and clamp in place of this switch, shall be used to join the antenna lead-in to the grounding conductor. The switch or flexible grounding lead may be located inside or outside the building. The base of the switch shall be of non-absorptive insulating material. The switch or flexible grounding lead shall be so mounted that its current-carrying parts will be at least 3 inches clear of the building wall or other conductors in the case of continuous-wave sets of 1000 watts and less, and in all other cases at least 5 inches. The conductor from grounding switch or flexible grounding lead to ground shall be securely supported. These provisions shall also apply to the connection of the counterpoise lead-in to its grounding conductor.

It is recommended that the switch be located in the most direct line between the lead-in conductors and the point where grounding connection is made.

h. Antenna and counterpoise conductors shall be effectively and permanently grounded at all times when station is not in actual operation and unattended, by a conductor at least as large as the lead-in and in no case smaller than No. 14 copper, bronze or approved copper-clad steel. This protective grounding conductor need not have an insulated covering or be mounted on insulating supports. The protective grounding conductor shall be run in as straight a line as possible to a good permanent ground. The ground connections shall be made to a cold-water pipe where such pipe is available and is in service and connected to the street mains. An outlet pipe from a water tank fed from a street main, or a well may be used, provided such outlet pipe is adequately bonded to the inlet pipe connected to the street water main or well. If water pipes are not available, ground connections may be made to a grounded steel frame of a building or to an artificial ground such as a galvanized iron pipe or a rod driven into permanently damp earth or to a metal plate or other body of metal buried similarly. The protective grounding conductor shall be protected where exposed to mechanical injury. A suitable approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping. Gas pipes shall not be used for the ground.

It is recommended that the protective grounding conductor be run outside the building.

i. The operating grounding conductor shall be of copper strip not less than $\frac{3}{8}$ inch wide by $\frac{1}{32}$ inch thick, or of copper bronze, or approved copper-clad steel having a periphery, or girth, of at least $\frac{3}{4}$ inch, such as a No. 2 wire, and shall be firmly secured in place throughout its length.

j. The operating grounding conductor shall be connected to a good permanent ground. Preference shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounding devices such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

k. Where the current supply is obtained directly from lighting or power circuits, the conductors whether or not lead-covered

shall be installed in approved metal conduit, armored cable or metal raceways.

l. When necessary to protect the supply system from high-potential surges and kick-backs there shall be installed in the supply line as near as possible to each radio-transformer, rotary spark gap, motor and generator in motor-generator sets and other auxiliary apparatus one of the following:

(1) Two condensers (each of not less than 1/10 microfarad capacity and capable of withstanding 600 volt test) in series across the line with mid-point between condensers grounded; across (in parallel with) each of these condensers shall be connected a shunting fixed spark-gap capable of not more than 1/32 inch separation.

(2) Two vacuum tube-type-protectors in series across the line with the mid-point grounded.

(3) Lightning arresters, such as the aluminum-cell type.

RADIO LAWS AND REGULATIONS OF THE UNITED STATES

AN ACT

For the regulation of radio communications, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act is intended to regulate all forms of interstate and foreign radio transmissions and communications within the United States, its Territories and possessions; to maintain the control of the United States over all the channels of interstate and foreign radio transmission; and to provide for the use of such channels, but not the ownership thereof, by individuals, firms, or corporations, for limited periods of time, under licenses granted by Federal authority, and no such license shall be construed to create any right, beyond the terms, conditions, and periods of the license. That no person, firm, company, or corporation shall use or operate any apparatus for the transmission of energy or communications or signals by radio (a) from one place in any Territory or possession of the United States or in the District of Columbia to another place in the same Territory, possession, or District; or (b) from any State, Territory, or possession of the United States, or from the District of Columbia to any other State, Territory, or possession of the United States; or (c) from any place in any State, Territory, or possession of the United States, or in the District of Columbia, to any place in any foreign country or to any vessel; or (d) within any State when the effects of such use extend beyond the borders of said State, or when interference is caused by such use or operation with the transmission of such energy, communications, or signals from within said State to any place beyond its borders, or from any place beyond its borders to any place within said State, or with the

transmission or reception of such energy, communications, or signals from and/or to places beyond the borders of said State; or (e) upon any vessel of the United States; or (f) upon any aircraft or other mobile stations within the United States, except under and in accordance with this Act and with a license in that behalf granted under the provisions of this Act.

Section 2. For the purposes of this Act, the United States is divided into five zones, as follows: The first zone shall embrace the States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, the District of Columbia, Porto Rico, and the Virgin Islands; the second zone shall embrace the States of Pennsylvania, Virginia, West Virginia, Ohio, Michigan, and Kentucky; the third zone shall embrace the States of North Carolina, South Carolina, Georgia, Florida, Alabama, Tennessee, Mississippi, Arkansas, Louisiana, Texas, and Oklahoma; the fourth zone shall embrace the States of Indiana, Illinois, Wisconsin, Minnesota, North Dakota, South Dakota, Iowa, Nebraska, Kansas, and Missouri; and the fifth zone shall embrace the States of Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California, the Territory of Hawaii, and Alaska.

Section 3. That a commission is hereby created and established to be known as the Federal Radio Commission, hereinafter referred to as the commission, which shall be composed of five commissioners appointed by the President, by and with the advice and consent of the Senate, and one of whom the President shall designate as chairman: *Provided*, That chairmen thereafter elected shall be chosen by the commission itself.

Each member of the commission shall be a citizen of the United States and an actual resident citizen of a State within the zone from which appointed at the time of said appointment. Not more than one commissioner shall be appointed from any zone. No member of the commission shall be financially interested in the manufacture or sale of radio apparatus or in the transmission or operation of radiotelegraphy, radiotelephony, or radio broadcasting. Not more than three commissioners shall be members of the same political party.

The first commissioners shall be appointed for the terms of two, three, four, five, and six years, respectively, from the date of the taking effect of this Act, the term of each to be designated by the President, but their successors shall be appointed for terms of six years, except that any person chosen to fill a vacancy shall be appointed only for the unexpired term of the commissioner whom he shall succeed.

The first meeting of the commission shall be held in the city of Washington at such time and place as the chairman of the commission may fix. The commission shall convene thereafter at such times and places as a majority of the commission may determine, or upon call of the chairman thereof.

The commission may appoint a secretary, and such clerks, special counsel, experts, examiners, and other employees as it may from time to time find necessary for the proper performance of its duties and as from time to time may be appropriated for by Congress.

The commission shall have an official seal and shall annually make a full report of its operations to the Congress.

The members of the commission shall receive a compensation of \$10,000 for the first year of their service, said year to date from the first meeting of said commission, and thereafter a compensation of \$30 per day for each day's attendance upon sessions of the commission or while engaged upon work of the commission and while traveling to and from such sessions, and also their necessary traveling expenses.

Section 4. Except as otherwise provided in this Act, the commission, from time to time, as public convenience, interest, or necessity requires, shall—

- (a) Classify radio stations;
- (b) Prescribe the nature of the service to be rendered by each class of licensed stations and each station within any class;
- (c) Assign bands of frequencies or wave lengths to the various classes of stations, and assign frequencies or wave lengths for each individual station and determine the power which each station shall use and the time during which it may operate;
- (d) Determine the location of classes of stations or individual stations:

(e) Regulate the kind of apparatus to be used with respect to its external effects and the purity and sharpness of the emissions from each station and from the apparatus therein;

(f) Make such regulations not inconsistent with law as it may deem necessary to prevent interference between stations and to carry out the provisions of this Act: *Provided, however,* That changes in the wave lengths, authorized power, in the character of emitted signals, or in the times of operation of any station, shall not be made without the consent of the station license unless, in the judgment of the commission, such changes will serve public necessity or the provisions of this Act will be more fully complied with;

(g) Have authority to establish areas or zones to be served by any station;

(h) Have authority to make special regulations applicable to radio stations engaged in chain broadcasting;

(i) Have authority to make general rules and regulations requiring stations to keep such records of programs, transmissions of energy, communications, or signals as it may deem desirable;

(j) Have authority to exclude from the requirements of any regulations in whole or in part any radio station upon railroad rolling stock, or to modify such regulations in its discretion;

(k) Have authority to hold hearings, summon witnesses, administer oaths, compel the production of books, documents, and papers and to make such investigations as may be necessary in the performance of its duties. The commission may make such expenditures (including expenditures for rent and personal services at the seat of government and elsewhere, for law books, periodicals, and books of reference, and for printing and binding) as may be necessary for the execution of the functions vested in the commission and, as from time to time may be appropriated for by Congress. All expenditures of the commission shall be allowed and paid upon the presentation of itemized vouchers therefor approved by the chairman.

Section 5. From and after one year after the first meeting of the commission created by this Act, all the powers and authority vested in the commission under the terms of this Act, except as to the revocation of licenses, shall be vested in and

exercised by the Secretary of Commerce; except that thereafter the commission shall have power and jurisdiction to act upon and determine any and all matters brought before it under the terms of this section.

It shall also be the duty of the Secretary of Commerce—

(A) For and during a period of one year from the first meeting of the commission created by this Act, to immediately refer to the commission all applications for station licenses or for the renewal or modification of existing station licenses.

(B) From and after one year from the first meeting of the commission created by this Act, to refer to the commission for its action any application for a station license or for the renewal or modification of any existing station license as to the granting of which dispute, controversy, or conflict arises or against the granting of which protest is filed within ten days after the date of filing said application by any party in interest and any application as to which such reference is requested by the applicant at the time of filing said application.

(C) To prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such persons as he finds qualified.¹

(D) To suspend the license of any operator for a period not exceeding two years upon proof sufficient to satisfy him that the licensee (a) has violated any provision of any act or treaty binding on the United States which the Secretary of Commerce or the commission is authorized by this Act to administer or by any regulation made by the commission or the Secretary of Commerce under any such Act or treaty; or (b) has failed to carry out the lawful orders of the master of the vessel on which he is employed; or (c) has willfully damaged or permitted radio apparatus to be damaged; or (d) has transmitted superfluous radio communications or signals or radio communications containing profane or obscene words or language; or (e) has willfully or maliciously interfered with any other radio communications or signals.

(E) To inspect all transmitting apparatus to ascertain whether in construction and operation it conforms to the requirements

¹ See Amendment, May 19, 1932, on page 407.

of this Act, the rules and regulations of the licensing authority, and the license under which it is constructed or operated.

(F) To report to the commission from time to time any violations of this Act, the rules, regulations, or orders of the commission, or of the terms or conditions of any license.

(G) To designate call letters of all stations.

(H) To cause to be published such call letters and such other announcements and data as in his judgment may be required for the efficient operation of radio stations subject to the jurisdiction of the United States and for the proper enforcement of this Act.

The Secretary may refer to the commission at any time any matter the determination of which is vested in him by the terms of this Act.

Any person, firm, company, or corporation, any State or political division thereof aggrieved or whose interests are adversely affected by any decision, determination, or regulation of the Secretary of Commerce may appeal therefrom to the commission by filing with the Secretary of Commerce notice of such appeal within thirty days after such decision or determination or promulgation of such regulation. All papers, documents, and other records, pertaining to such application on file with the Secretary shall thereupon be transferred by him to the commission. The commission shall hear such appeal *de novo* under such rules and regulations as it may determine.

Decisions by the commission as to matters so appealed and as to all other matters over which it has jurisdiction shall be final, subject to the right of appeal herein given.

No station license shall be granted by the commission or the Secretary of Commerce until the applicant therefor shall have signed a waiver of any claim to the use of any particular frequency or wave length or of the ether as against the regulatory power of the United States because of the previous use of the same, whether by license or otherwise.

Section 6. Radio stations belonging to and operated by the United States shall not be subject to the provisions of sections 1, 4, and 5 of this Act. All such Government stations shall use such frequencies or wave lengths as shall be assigned to each or to each class by the President. All such stations, except stations

on board naval and other Government vessels while at sea or beyond the limits of the continental United States, when transmitting any radio communication or signal other than a communication or signal relating to Government business shall conform to such rules and regulations designed to prevent interference with other radio stations and the rights of others as the licensing authority may prescribe. Upon proclamation by the President that there exists war or a threat of war or a state of public peril or disaster or other national emergency, or in order to preserve the neutrality of the United States, the President may suspend or amend, for such time as he may see fit, the rules and regulations applicable to any or all stations within the jurisdiction of the United States as prescribed by the licensing authority, and may cause the closing of any station for radio communication and the removal therefrom of its apparatus and equipment, or he may authorize the use or control of any such station and/or its apparatus and equipment by any department of the Government under such regulations as he may prescribe, upon just compensation to the owners. Radio stations on board vessels of the United States Shipping Board or the United States Shipping Board Emergency Fleet Corporation or the Inland and Coastwise Waterways Service shall be subject to the provisions of this Act.

Section 7. The President shall ascertain the just compensation for such use or control and certify the amount ascertained to Congress for appropriation and payment to the person entitled thereto. If the amount so certified is unsatisfactory to the person entitled thereto, such person shall be paid only 75 per centum of the amount and shall be entitled to sue the United States to recover such further sum as added to such payment of 75 per centum which will make such amount as will be just compensation for the use and control. Such suit shall be brought in the manner provided by paragraph 20 of section 24, or by section 145 of the Judicial Code, as amended.

Section 8. All stations owned and operated by the United States, except mobile stations of the Army of the United States, and all other stations on land and sea, shall have special call letters designated by the Secretary of Commerce.

Section 1 of this Act shall not apply to any person, firm, company, or corporation sending radio communications or signals on a foreign ship while the same is within the jurisdiction of the United States, but such communications or signals shall be transmitted only in accordance with such regulations designed to prevent interference as may be promulgated under the authority of this Act.

Section 9. The licensing authority, if public convenience, interest, or necessity will be served thereby, subject to the limitations of this Act, shall grant to any applicant therefor a station license provided for by this Act.

In considering applications for licenses and renewals of licenses, when and in so far as there is a demand for the same, the licensing authority shall make such a distribution of licenses, bands of frequency or wave lengths, periods of time for operation, and of power among the different States and communities as to give fair, efficient, and equitable radio service to each of the same.¹

No license granted for the operation of a broadcasting station shall be for a longer term than three years and no license so granted for any other class of station shall be for a longer term than five years, and any license granted may be revoked as hereinafter provided. Upon the expiration of any license, upon application therefor, a renewal of such license may be granted from time to time for a term not to exceed three years in the case of broadcasting licenses and not to exceed five years in the case of other licenses.

No renewal of an existing station license shall be granted more than thirty days prior to the expiration of the original license.

Section 10. The licensing authority may grant station licenses only upon written application therefor addressed to it. All applications shall be filed with the Secretary of Commerce. All such applications shall set forth such facts as the licensing authority by regulation may prescribe as to the citizenship, character, and financial, technical, and other qualifications of the applicant to operate the station; the ownership and location of

¹ See Amendment, March 28, 1928, on page 402.

the proposed station and of the stations, if any, with which it is proposed to communicate; the frequencies or wave lengths and the power desired to be used; the hours of the day or other periods of time during which it is proposed to operate the station; the purposes for which the station is to be used; and such other information as it may require. The licensing authority at any time after the filing of such original application and during the term of any such license, may require from an applicant or licensee further written statements of fact to enable it to determine whether such original application should be granted or denied or such license revoked. Such application and/or such statement of fact shall be signed by the applicant and/or licensee under oath or affirmation.

The licensing authority in granting any license for a station intended or used for commercial communication between the United States or any Territory or possession, continental or insular, subject to the jurisdiction of the United States, and any foreign country, may impose any terms, conditions, or restrictions authorized to be imposed with respect to submarine-cable licenses by section 2 of an Act entitled "An Act relating to the landing and the operation of submarine cables in the United States," approved May 24, 1921.

Section 11. If upon examination of any application for a station license or for the renewal or modification of a station license the licensing authority shall determine that public interest, convenience, or necessity would be served by the granting thereof, it shall authorize the issuance, renewal, or modification thereof in accordance with said finding. In the event the licensing authority upon examination of any such application does not reach such decision with respect thereto, it shall notify the applicant thereof, shall fix and give notice of a time and place for hearing thereon, and shall afford such applicant an opportunity to be heard under such rules and regulations as it may prescribe.

Such station licenses as the licensing authority may grant shall be in such general form as it may prescribe, but each license shall contain, in addition to other provisions, a statement of the following conditions to which such license shall be subject

(A) The station license shall not vest in the licensee any right to operate the station nor any right in the use of the frequencies or wave length designated in the license beyond the term thereof nor in any other manner than authorized therein.

(B) Neither the license nor the right granted thereunder shall be assigned or otherwise transferred in violation of this Act.

(C) Every license issued under this Act shall be subject in terms to the right of use or control conferred by section 6 hereof.

In cases of emergency arising during the period of one year from and after the first meeting of the commission created hereby, or on applications filed during said time for temporary changes in terms of licenses when the commission is not in session and prompt action is deemed necessary, the Secretary of Commerce shall have authority to exercise the powers and duties of the commission, except as to revocation of licenses, but all such exercise of powers shall be promptly reported to the members of the commission, and any action by the Secretary authorized under this paragraph shall continue in force and have effect only until such time as the commission shall act thereon.

Section 12. The station license required hereby shall not be granted to, or after the granting thereof such license shall not be transferred in any manner, either voluntarily or involuntarily, to (a) any alien or the representative of any alien; (b) to any foreign government, or the representative thereof; (c) to any company, corporation, or association organized under the laws of any foreign government; (d) to any company, corporation, or association of which any officer or director is an alien, or of which more than one-fifth of the capital stock may be voted by aliens or their representatives or by a foreign government or representative thereof, or by any company, corporation, or association organized under the laws of a foreign country.

The station license required hereby, the frequencies or wave length or lengths authorized to be used by the licensee, and the rights therein granted shall not be transferred, assigned, or in any manner, either voluntarily or involuntarily, disposed of to any person, firm, company, or corporation without the consent in writing of the licensing authority.

Section 13. The licensing authority is hereby directed to refuse a station license and/or the permit hereinafter required for the construction of a station to any person, firm, company, or corporation, or any subsidiary thereof, which has been found guilty by any Federal court of unlawfully monopolizing or attempting unlawfully to monopolize, after this Act takes effect, radio communication, directly or indirectly, through the control of the manufacture or sale of radio apparatus, through exclusive traffic arrangements, or by any other means or to have been using unfair methods of competition. The granting of a license shall not estop the United States or any person aggrieved from proceeding against such person, firm, company, or corporation for violating the law against unfair methods of competition or for a violation of the law against unlawful restraints and monopolies and/or combinations, contracts, or agreements in restraint of trade, or from instituting proceedings for the dissolution of such firm, company, or corporation.

Section 14. Any station license shall be revocable by the commission for false statements either in the application or in the statement of fact which may be required by section 10 hereof, or because of conditions revealed by such statements of fact as may be required from time to time which would warrant the licensing authority in refusing to grant a license or an original application, or for failure to operate substantially as set forth in the license, for violation of or failure to observe any of the restrictions and conditions of this Act, or of any regulation of the licensing authority authorized by this Act or by a treaty ratified by the United States, or whenever the Interstate Commerce Commission, or any other Federal body in the exercise of authority conferred upon it by law, shall find, and shall certify to the commission that any licensee bound so to do, has failed to provide reasonable facilities for the transmission of radio communications, or that any licensee has made any unjust and unreasonable charge, or has been guilty of any discrimination, either as to charge or as to service or has made or prescribed any unjust and unreasonable classification, regulation, or practice with respect to the transmission of radio communications or service: *Provided*, That no such order of revocation shall take

effect until thirty days' notice in writing thereof, stating the cause for the proposed revocation, has been given to the parties known by the commission to be interested in such license. Any person in interest aggrieved by said order may make written application to the commission at any time within said thirty days for a hearing upon such order, and upon the filing of such written application said order of revocation shall stand suspended until the conclusion of the hearing herein directed. Notice in writing of said hearing shall be given by the commission to all the parties known to it to be interested in such license twenty days prior to the time of said hearing. Said hearing shall be conducted under such rules and in such manner as the commission may prescribe. Upon the conclusion hereof the commission may affirm, modify, or revoke said orders of revocation.

Section 15. All laws of the United States relating to unlawful restraints and monopolies and to combinations, contracts, or agreements in restraint of trade are hereby declared to be applicable to the manufacture and sale of and to trade in radio apparatus and devices entering into or affecting interstate or foreign commerce and to interstate or foreign radio communications. Whenever in any suit, action, or proceeding, civil or criminal, brought under the provisions of any of said laws or in any proceedings brought to enforce or to review findings and orders of the Federal Trade Commission or other governmental agency in respect of any matters as to which said commission or other governmental agency is by law authorized to act, any licensee shall be found guilty of the violation of the provisions of such laws or any of them, the court, in addition to the penalties imposed by said laws, may adjudge, order, and/or decree that the license of such licensee shall, as of the date the decree or judgment becomes finally effective or as of such other date as the said decree shall fix, be revoked and that all rights under such license shall thereupon cease: *Provided, however,* That such licensee shall have the same right of appeal or review as is provided by law in respect of other decrees and judgments of said court.

Section 16. Any applicant for a construction permit, for a station license, or for the renewal or modification of an existing

station license whose application is refused by the licensing authority shall have the right to appeal from said decision to the Court of Appeals of the District of Columbia; and any licensee whose license is revoked by the commission shall have the right to appeal from such decision of revocation to said Court of Appeals of the District of Columbia or to the district court of the United States in which the apparatus licensed is operated, by filing with said court, within twenty days after the decision complained of is effective, notice in writing of said appeal and of the reasons therefor.

The licensing authority from whose decision an appeal is taken shall be notified of said appeal by service upon it, prior to the filing thereof, of a certified copy of said appeal and of the reasons therefor. Within twenty days after the filing of said appeal the licensing authority shall file with the court the originals or certified copies of all papers and evidence presented to it upon the original application for a permit or license or in the hearing upon said order of revocation, and also a like copy of its decision thereon and a full statement in writing of the facts and the grounds for its decision as found and given by it. Within twenty days after the filing of said statement by the licensing authority either party may give notice to the court of his desire to adduce additional evidence. Said notice shall be in the form of a verified petition stating the nature and character of said additional evidence, and the court may thereupon order such evidence to be taken in such matter and upon such terms and conditions as it may deem proper.

At the earliest convenient time the court shall hear, review, and determine the appeal upon said record and evidence, and may alter or revise the decision appealed from and enter such judgment as to it may seem just. The revision by the court shall be confined to the points set forth in the reasons of appeal.¹

Section 17. After the passage of this Act no person, firm, company, or corporation now or hereafter directly or indirectly through any subsidiary, associated, or affiliated person, firm, company, corporation, or agent, or otherwise, in the business of transmitting and/or receiving for hire energy, communications,

¹ See Amendment, July 1, 1930, on page 406.

or signals by radio in accordance with the terms of the license issued under this Act, shall by purchase, lease, construction, or otherwise, directly or indirectly, acquire, own, control, or operate any cable or wire telegraph or telephone line or system between any place in any State, Territory, or possession of the United States or in the District of Columbia, and any place in any foreign country, or shall acquire, own, or control any part of the stock or other capital share of any interest in the physical property and/or other assets of any such cable, wire, telegraph, or telephone line or system, if in either case the purpose is and/or the effect thereof may be to substantially lessen competition or to restrain commerce between any place in any State, Territory, or possession of the United States or in the District of Columbia and any place in any foreign country, or unlawfully to create monopoly in any line of commerce; nor shall any person, firm, company, or corporation now or hereafter engaged directly or indirectly through any subsidiary, associated or affiliated person, company, corporation, or agent, or otherwise, in the business of transmitting or receiving for hire messages by any cable, wire, telegraph, or telephone line or system (a) between any place in any State, Territory, or possession of the United States or in the District of Columbia, and any place in any other State, Territory, or possession of the United States; or (b) between any place in any State, Territory, or possession of the United States, or the District of Columbia, and any place in any foreign country, by purchase, lease, construction, or otherwise, directly or indirectly acquire, own, control, or operate any station or the apparatus therein, or any system for transmitting and/or receiving radio communications or signals between any place in any State, Territory, or possession of the United States or in the District of Columbia, and any place in any foreign country, or shall acquire, own, or control any part of the stock or other capital share or any interest in the physical property and/or other assets of any such radio station, apparatus, or system, if in either case the purpose is and/or the effect thereof may be to substantially lessen competition or to restrain commerce between any place in any State, Territory, or possession of the United States or in the District of Columbia, and any

place in any foreign country, or unlawfully to create monopoly in any line of commerce.

Section 18. If any licensee shall permit any person who is a legally qualified candidate for any public office to use a broadcasting station, he shall afford equal opportunities to all other such candidates for that office in the use of such broadcasting station, and the licensing authority shall make rules and regulations to carry this provision into effect: *Provided*, That such licensee shall have no power of censorship over the material broadcast under the provisions of this paragraph. No obligation is hereby imposed upon any licensee to allow the use of its station by any such candidate.

Section 19. All matter broadcast by any radio station for which service, money, or any other valuable consideration is directly or indirectly paid, or promised to or charged or accepted by, the station so broadcasting, from any person, firm, company, or corporation, shall at the time the same is so broadcast, be announced as paid for or furnished, as the case may be, by such person, firm, company, or corporation.

Section 20. The actual operation of all transmitting apparatus in any radio station for which a station license is required by this Act shall be carried on only by a person holding an operator's license issued hereunder. No person shall operate any such apparatus in such station except under and in accordance with an operator's license issued to him by the Secretary of Commerce.

Section 21. No license shall be issued under the authority of this Act for the operation of any station the construction of which is begun or is continued after this Act takes effect, unless a permit for its construction has been granted by the licensing authority upon written application therefor. The licensing authority may grant such permit if public convenience, interest, or necessity will be served by the construction of the station. This application shall set forth such facts as the licensing authority by regulation may prescribe as to the citizenship, character, and the financial, technical, and other ability of the applicant to construct and operate the station, the ownership and location of the proposed station and of the station or stations

with which it is proposed to communicate, the frequencies and wave length or wave lengths desired to be used, the hours of the day or other periods of time during which it is proposed to operate the station, the purpose for which the station is to be used, the type of transmitting apparatus to be used, the power to be used, the date upon which the station is expected to be completed and in operation, and such other information as the licensing authority may require. Such application shall be signed by the applicant under oath or affirmation.

Such permit for construction shall show specifically the earliest and latest dates between which the actual operation of such station is expected to begin, and shall provide that said permit will be automatically forfeited if the station is not ready for operation within the time specified or within such further time as the licensing authority may allow, unless prevented by causes not under the control of the grantee. The rights under any such permit shall not be assigned or otherwise transferred to any person, firm, company, or corporation without the approval of the licensing authority. A permit for construction shall not be required for Government stations, amateur stations, or stations upon mobile vessels, railroad rolling stock, or aircraft. Upon the completion of any station for the construction or continued construction of which a permit has been granted, and upon it being made to appear to the licensing authority that all the terms, conditions, and obligations set forth in the application and permit have been fully met, and that no cause or circumstance arising or first coming to the knowledge of the licensing authority since the granting of the permit would, in the judgment of the licensing authority, make the operation of such station against the public interest, the licensing authority shall issue a license to the lawful holder of said permit for the operation of said station. Said license shall conform generally to the terms of said permit.

Section 22. The licensing authority is authorized to designate from time to time radio stations the communications or signals of which, in its opinion, are liable to interfere with the transmission or reception of distress signals of ships. Such stations are required to keep a licensed radio operator listening in on

the wave lengths designated for signals of distress and radio communications relating thereto during the entire period the transmitter of such station is in operation.

Section 23. Every radio station on shipboard shall be equipped to transmit radio communications or signals of distress on the frequency or wave length specified by the licensing authority, with apparatus capable of transmitting and receiving messages over a distance of at least one hundred miles by day or night. When sending radio communications or signals of distress and radio communications relating thereto the transmitting set may be adjusted in such a manner as to produce a maximum of radiation irrespective of the amount of interference which may thus be caused.

All radio stations, including Government stations and stations on board foreign vessels when within the territorial waters of the United States, shall give absolute priority to radio communications or signals relating to ships in distress; shall cease all sending on frequencies or wave lengths which will interfere with hearing a radio communication or signal of distress, and, except when engaged in answering or aiding the ship in distress, shall refrain from sending any radio communications or signals until there is assurance that no interference will be caused with the radio communications or signals relating thereto, and shall assist the vessel in distress, so far as possible, by complying with its instructions.

Section 24. Every shore station open to general public service between the coast and vessels at sea shall be bound to exchange radio communications or signals with any ship station without distinction as to radio systems or instruments adopted by such stations, respectively, and each station on shipboard shall be bound to exchange radio communications or signals with any other station on shipboard without distinction as to radio systems or instruments adopted by each station.

Section 25. At all places where Government and private or commercial radio stations on land operate in such close proximity that interference with the work of Government stations can not be avoided when they are operating simultaneously such private or commercial stations as do interfere with the transmission or

reception of radio communications or signals by the Government stations concerned shall not use their transmitters during the first fifteen minutes of each hour, local standard time.

The Government stations for which the above-mentioned division of time is established shall transmit radio communications or signals only during the first fifteen minutes of each hour, local standard time, except in case of signals of radio communications relating to vessels in distress, and vessel requests for information as to course, location, or compass direction.

Section 26. In all circumstances, except in case of radio communications or signals relating to vessels in distress, all radio stations, including those owned and operated by the United States, shall use the minimum amount of power necessary to carry out the communication desired.

Section 27. No person receiving or assisting in receiving any radio communication shall divulge or publish the contents, substance, purport, effect, or meaning thereof except through authorized channels of transmission or reception to any person other than the addressee, his agent, or attorney, or to a telephone, telegraph, cable, or radio station employed or authorized to forward such radio communication to its destination, or to proper accounting or distributing officers of the various communicating centers over which the radio communication may be passed, or to the master of a ship under whom he is serving, or in response to a subpoena issued by a court of competent jurisdiction, or on demand of other lawful authority; and no person not being authorized by the sender shall intercept any message and divulge or publish the contents, substance, purport, effect, or meaning of such intercepted message to any person; and no person not being entitled thereto shall receive or assist in receiving any radio communication and use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto; and no person having received such intercepted radio communication or having become acquainted with the contents, substance, purport, effect, or meaning of the same or any part thereof, knowing that such information was so obtained, shall divulge or publish the contents, substance, purport, effect, or meaning of the same or any part

thereof, or use the same or any information therein contained for his own benefit or for the benefit of another not entitled thereto: *Provided*, That this section shall not apply to the receiving, divulging, publishing, or utilizing the contents of any radio communication broadcasted or transmitted by amateurs or others for the use of the general public or relating to ships in distress.

Section 28. No person, firm, company, or corporation within the jurisdiction of the United States shall knowingly utter or transmit, or cause to be uttered or transmitted, any false or fraudulent signal of distress, or communication relating thereto, nor shall any broadcasting station rebroadcast the program or any part thereof of another broadcasting station without the express authority of the originating station.

Section 29. Nothing in this Act shall be understood or construed to give the licensing authority the power of censorship over the radio communications or signals transmitted by any radio station, and no regulation or condition shall be promulgated or fixed by the licensing authority which shall interfere with the right of free speech by means of radio communications. No person within the jurisdiction of the United States shall utter any obscene, indecent, or profane language by means of radio communication.

Section 30. The Secretary of the Navy is hereby authorized unless restrained by international agreement, under the terms and conditions and at rates prescribed by him, which rates shall be just and reasonable, and which, upon complaint, shall be subject to review and revision by the Interstate Commerce Commission, to use all radio stations and apparatus, wherever located, owned by the United States and under the control of the Navy Department (a) for the reception and transmission of press messages offered by any newspaper published in the United States, its Territories or possessions, or published by citizens of the United States in foreign countries, or by any press association of the United States, and (b) for the reception and transmission of private commercial messages between ships, between ship and shore, between localities in Alaska and between Alaska and the continental United States: *Provided*, That the rates fixed for the reception and transmission of all such messages, other than

press messages between the Pacific coast of the United States, Hawaii, Alaska, the Philippine Islands, and the Orient, and between the United States and the Virgin Islands, shall not be less than the rates charged by privately owned and operated stations for like messages and service: *Provided further*, That the right to use such stations for any of the purposes named in this section shall terminate and cease as between any countries or localities or between any locality and privately operated ships whenever privately owned and operated stations are capable of meeting the normal communication requirements between such countries or localities or between any locality and privately operated ships, and the licensing authority shall have notified the Secretary of the Navy thereof.

Section 31. The expression "radio communication" or "radio communications" wherever used in this Act means any intelligence, message, signal, power, pictures, or communication of any nature transferred by electrical energy from one point to another without the aid of any wire connecting the points from and at which the electrical energy is sent or received and any system by means of which such transfer of energy is effected.

Section 32. Any person, firm, company, or corporation failing or refusing to observe or violating any rule, regulation, restriction, or condition made or imposed by the licensing authority under the authority of this Act or of any international radio convention or treaty ratified or adhered to by the United States, in addition to any other penalties provided by law, upon conviction thereof by a court of competent jurisdiction, shall be punished by a fine of not more than \$500 for each and every offense.

Section 33. Any person, firm, company, or corporation who shall violate any provision of this Act, or shall knowingly make any false oath or affirmation in any affidavit required or authorized by this Act, or shall knowingly swear falsely to a material matter in any hearing authorized by this Act, upon conviction thereof in any court of competent jurisdiction shall be punished by a fine of not more than \$5,000 or by imprisonment for a term of not more than five years or both for each and every such offense.

Section 34. The trial of any offense under this Act shall be in

the district in which it is committed; or if the offense is committed upon the high seas, or out of the jurisdiction of any particular State or district, the trial shall be in the district where the offender may be found or into which he shall be first brought.

Section 35. This Act shall not apply to the Philippine Islands or to the Canal Zone. In international radio matters the Philippine Islands and the Canal Zone shall be represented by the Secretary of State.

Section 36. The licensing authority is authorized to designate any officer or employee of any other department of the Government on duty in any Territory or possession of the United States other than the Philippine Islands and the Canal Zone, to render therein such services in connection with the administration of the radio laws of the United States as such authority may prescribe: *Provided*, That such designation shall be approved by the head of the department in which such person is employed.

Section 37. The unexpended balance of the moneys appropriated in the item for "wireless communication laws," under the caption "Bureau of Navigation" in Title III of the Act entitled "An Act making appropriations for the Departments of State and Justice and for the judiciary, and for the Departments of Commerce and Labor, for the fiscal year ending June 30, 1927, and for other purposes," approved April 29, 1926, and the appropriation for the same purposes for the fiscal year ending June 30, 1928, shall be available both for expenditures incurred in the administration of this Act and for expenditures for the purposes specified in such items. There is hereby authorized to be appropriated for each fiscal year such sums as may be necessary for the administration of this Act and for the purposes specified in such item.

Section 38. If any provision of this Act or the application thereof to any person, firm, company, or corporation, or to any circumstances, is held invalid, the remainder of the Act and the application of such provision to other persons, firms, companies, or corporations, or to other circumstances, shall not be affected thereby.

Section 39. The Act entitled "An Act to regulate radio com-

munication," approved August 13, 1912, the joint resolution to authorize the operation of Government-owned radio stations for the general public, and for other purposes, approved June 5, 1920, as amended, and the joint resolution entitled "Joint resolution limiting the time for which licenses for radio transmission may be granted, and for other purposes," approved December 8, 1926, are hereby replaced.

Such repeal, however, shall affect any act done or any right accrued or any suit or proceeding had or commenced in any civil cause prior to said repeal, but all liabilities under said laws shall continue and may be enforced in the same manner as if committed; and all penalties, forfeitures, or liabilities incurred prior to taking effect hereof, under any law embraced in, changed, modified, or repealed by this Act, may be prosecuted and punished in the same manner and with the same effect as if this Act had not been passed.

Nothing in this section shall be construed as authorizing any person now using or operating any apparatus for the transmission of radio energy or radio communications or signals to continue such use except under and in accordance with this Act and with a license granted in accordance with the authority hereinbefore conferred.

Section 40. This Act shall take effect and be in force upon its passage and approval, except that for and during a period of sixty days after such approval no holder of a license or an extension thereof issued by the Secretary of Commerce under said Act of August 13, 1912, shall be subject to the penalties provided herein for operating a station without the license herein provided.

Section 41. This Act may be referred to and cited as the Radio Act of 1927. (Approved, Feb. 23, 1927.)

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all the powers and authority vested in the Federal Radio Commission by the Radio Act of 1927, approved February 23, 1927, shall continue to be vested in and exercised by the commission until March 16, 1929; and wherever any reference is made in such Act to the period of one year after the first meeting of the com-

mission, such reference shall be held to mean the period of two years after the first meeting of the commission.

Section 2. The period during which the members of the commission shall receive compensation at the rate of \$10,000 per annum is hereby extended until March 16, 1929.

Section 3. Prior to January 1, 1930, the licensing authority shall grant no license or renewal of license under the Radio Act of 1927 for a broadcasting station for a period to exceed three months and no license or renewal of license for any other class of station for a period to exceed one year.

Section 4. The term of office of each member of the commission shall expire on February 23, 1929, and thereafter commissioners shall be appointed for terms of two, three, four, five, and six years, respectively, as provided in the Radio Act of 1927.

Section 5. The second paragraph of section 9 of the Radio Act of 1927 is amended to read as follows:

"It is hereby declared that the people of all the zones established by section 2 of this Act are entitled to equality of radio broadcasting service, both of transmission and of reception, and in order to provide said equality the licensing authority shall as nearly as possible make and maintain an equal allocation of broadcasting licenses, of bands of frequency or wave lengths, of periods of time for operation, and of station power, to each of said zones when and in so far as there are applications therefor; and shall make a fair and equitable allocation of licenses, wave lengths, time for operation and station power to each of the States, the District of Columbia, the Territories and possessions of the United States within each zone, according to population. The licensing authority shall carry into effect the equality of broadcasting service hereinbefore directed, whenever necessary or proper, by granting or refusing licenses or renewals of licenses, by changing periods of time for operation, and by increasing or decreasing station power, when applications are made for licenses or renewals of licenses: *Provided*, That if and when there is a lack of applications from any zone for the proportionate share of licenses, wave lengths, time of operation, or station power to which such zone is entitled, the licensing authority may issue licenses for the balance of the proportion not applied for from

any zone, to applicants from other zones for a temporary period of ninety days each, and shall specifically designate that said apportionment is only for said temporary period. Allocations shall be charged to the State, District, Territory, or possession wherein the studio of the station is located and not where the transmitter is located." (Approved, March 28, 1928.)

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all the powers and authority vested in the Federal Radio Commission by the Radio Act of 1927, approved February 23, 1927, shall continue to be vested in and exercised by the commission until December 31, 1929; and wherever any reference is made in such Act to the period of one year after the first meeting of the commission, such reference shall be held to mean the period until December 31, 1929.

Section 2. The period during which the members of the commission shall receive compensation at the rate of \$10,000 per annum is hereby extended until March 16, 1930.

Section 3. Prior to January 1, 1931, the licensing authority shall grant no license or renewal of license under the Radio Act of 1927 for a broadcasting station for a period to exceed three months and no license or renewal of license for any other class of station for a period to exceed one year.

Section 4. The term of office of each member of the commission shall expire on February 23, 1930, and thereafter commissioners shall be appointed for terms of two, three, four, five, and six years, respectively, as provided in the Radio Act of 1927.

Section 5. The commission is authorized to appoint a general counsel and pay him a salary of \$10,000 per annum and not to exceed three assistants to such general counsel, at salaries of \$7,500 each per annum. It may appoint such other legal assistants as it may from time to time find necessary for the proper performance of its duties and as from time to time may be appropriated for by Congress. (Approved, March 4, 1929.)

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all the powers and authority vested in the Federal Radio Commission by the Radio Act of 1927, as amended, shall continue to be vested

in and exercised by the commission until otherwise provided for by law; and wherever any reference is made in such Act to the period of one year after the first meeting of the commission, such period of one year is hereby extended until such time as is otherwise provided for by law.

SEC. 2. The period during which the members of the commission shall receive compensation at the rate of \$10,000 per annum is hereby extended until such time as is otherwise provided for by law.

SEC. 3. The commission is authorized to appoint a chief engineer who shall receive a salary of \$10,000 per annum, and not to exceed two assistants to such chief engineer at salaries not to exceed \$7,500 each per annum. It may appoint such other technical assistants as it may from time to time find necessary for the proper performance of its duties and as from time to time may be appropriated for by Congress. (Approved, December 18, 1929.)

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 16 of the Radio Act of 1927 (U. S. C., Supp. III, title 47, sec. 96) is amended by striking out the whole of said section and by inserting in lieu thereof the following:

"SEC. 16. (a) An appeal may be taken, in the manner hereinafter provided, from decisions of the commission to the Court of Appeals of the District of Columbia in any of the following cases:

"(1) By any applicant for a station license, or for renewal of an existing station license, or for modification of an existing station license, whose application is refused by the commission.

"(2) By any licensee whose license is revoked, modified, or suspended by the commission.

"(3) By any other person, firm, or corporation aggrieved or whose interests are adversely affected by any decision of the commission granting or refusing any such application or by any decision of the commission revoking, modifying, or suspending an existing station license.

"Such appeal shall be taken by filing with said court within twenty days after the decision complained of is effective, notice in writing of said appeal and a statement of the reasons therefor,

together with proof of service of a true copy of said notice and statement upon the commission. Unless a later date is specified by the commission as part of its decision, the decision complained of shall be considered to be effective as of the date on which public announcement of the decision is made at the office of the commission in the city of Washington.

“(b) The commission shall thereupon immediately, and in any event not later than five days from the date of such service upon it, mail or otherwise deliver a copy of said notice of appeal to each person, firm, or corporation shown by the records of the commission to be interested in such appeal and to have a right to intervene therein under the provisions of this section, and shall at all times thereafter permit any such person, firm, or corporation to inspect and make copies of the appellant’s statement of reasons for said appeal at the office of the commission in the city of Washington. Within thirty days after the filing of said appeal the commission shall file with the court the originals or certified copies of all papers and evidence presented to it upon the application involved or upon its order revoking, modifying, or suspending a license, and also a like copy of its decision thereon, and shall within thirty days thereafter file a full statement in writing of the facts and grounds for its decision as found and given by it, and a list of all interested persons, firms, or corporations to whom it has mailed or otherwise delivered a copy of said notice of appeal.

“(c) Within thirty days after the filing of said appeal any interested person, firm, or corporation may intervene and participate in the proceedings had upon said appeal by filing with the court a notice of intention to intervene and a verified statement showing the nature of the interest of such party, together with proof of service of true copies of said notice and statement, both upon appellant and upon the commission. Any person, firm, or corporation who would be aggrieved or whose interests would be adversely affected by a reversal or modification of the decision of the commission complained of shall be considered an interested party.

“(d) At the earliest convenient time the court shall hear and determine the appeal upon the record before it, and shall have

power, upon such record, to enter a judgment affirming or reversing the decision of the commission, and, in event the court shall render a decision and enter an order reversing the decision of the commission, it shall remand the case to the commission to carry out the judgment of the court: *Provided, however*, That the review by the court shall be limited to questions of law and that findings of fact by the commission, if supported by substantial evidence, shall be conclusive unless it shall clearly appear that the findings of the commission are arbitrary or capricious. The court's judgment shall be final, subject, however, to review by the Supreme Court of the United States upon writ of certiorari on petition therefor under section 347 of title 28 of the Judicial Code by appellant, by the commission, or by any interested party intervening in the appeal.

“(e) The court may, in its discretion, enter judgment for costs in favor of or against an appellant, and/or other interested parties intervening in said appeal, but not against the commission, depending upon the nature of the issues involved upon said appeal and the outcome thereof: *Provided, however*, That this section shall not relate to or affect appeals which were filed in said Court of Appeals prior to the enactment of this amendment.” (Approved, July 1, 1930.)

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the following sums are appropriated, out of any money in the Treasury not otherwise appropriated, for the fiscal year 1930 for salaries and expenses of the Federal Radio Commission as continued by the Act approved December 18, 1929, namely:

For an additional amount for the pay of five commissioners at the rate of \$10,000 each per annum, \$5,000;

For an additional amount for all other authorized expenses of the Federal Radio Commission in performing the duties imposed by the Radio Act of 1927, as amended, including personal services, newspapers and periodicals, law and reference books, special counsel fees, printing and binding, supplies and equipment which, when the aggregate amount involved does not exceed \$25, may be purchased without regard to section 3709 of the Revised Statutes (United States Code, title 41, section 5), contract

stenographic reporting services without reference to such section, travel and other necessary expenses, \$26,000; and in addition thereto \$75,000 of the unexpended balance of the appropriation "Salaries and Expenses, Federal Radio Commission, 1927-1929" is hereby reappropriated and made available for the purposes of the appropriation "Salaries and Expenses, Federal Radio Commission, 1930," all to be retroactive to the date of the approval of such Act of December 18, 1929. (Approved, February 1, 1930.)

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That section 5, subparagraph C of the Act of February 23, 1927, as amended (U. S. C., title 47, sec. 85), is amended by striking out the word "persons" after the words "issue them to such" and inserting the words "citizens of the United States," so that the amended paragraph will read: "to prescribe the qualifications of station operators, to classify them according to the duties to be performed, to fix the forms of such licenses, and to issue them to such citizens of the United States as he finds qualified." (Approved, May 19, 1932.)

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